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EFFICIENCY TESTS OF LUBRICATING OILS

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The tests described in this paper were made at the Case School of Applied Science, Cleveland, O., and had for their object:

a To determine the relation between the viscosity and the wearing and lubricating qualities of the oils.

b To determine the effect of the constituents of the various oils on the lubricating qualities.

2 Twenty-two oils were tested, the method of procedure being to find the chemical composition and viscosity of each oil and then to use it as a lubricant in a journal bearing. The temperature and frictional resistance were observed for a given length of time under a known load and speed. Previous experiments have left the question of the relation between viscosity and friction rather unsettled, but it is probable that if the load selected is a suitable one for a given oil then the friction will increase if the viscosity is increased. There seems to be no positive relation established between the viscosity and the wearing qualities of oils.

3 The lubricating quality of an oil is determined by its ability to maintain a continuous film over the lubricated surface, keeping the rubbing parts from direct contact. The coefficient of friction is the frictional resistance to motion of the journal, in pounds, divided by the load on the journal. The viscosity of an oil is measured by its resistance to flow, a strong resistance to flow indicating a high viscosity.

4 The apparatus used in these tests is shown in Fig. 1.[1] The pulley D on the shaft B is driven from a countershaft, having tight and loose pulleys. The journal E, upon which the tests were made,

[1] This machine was designed and built by Prof. C. H. Benjamin.

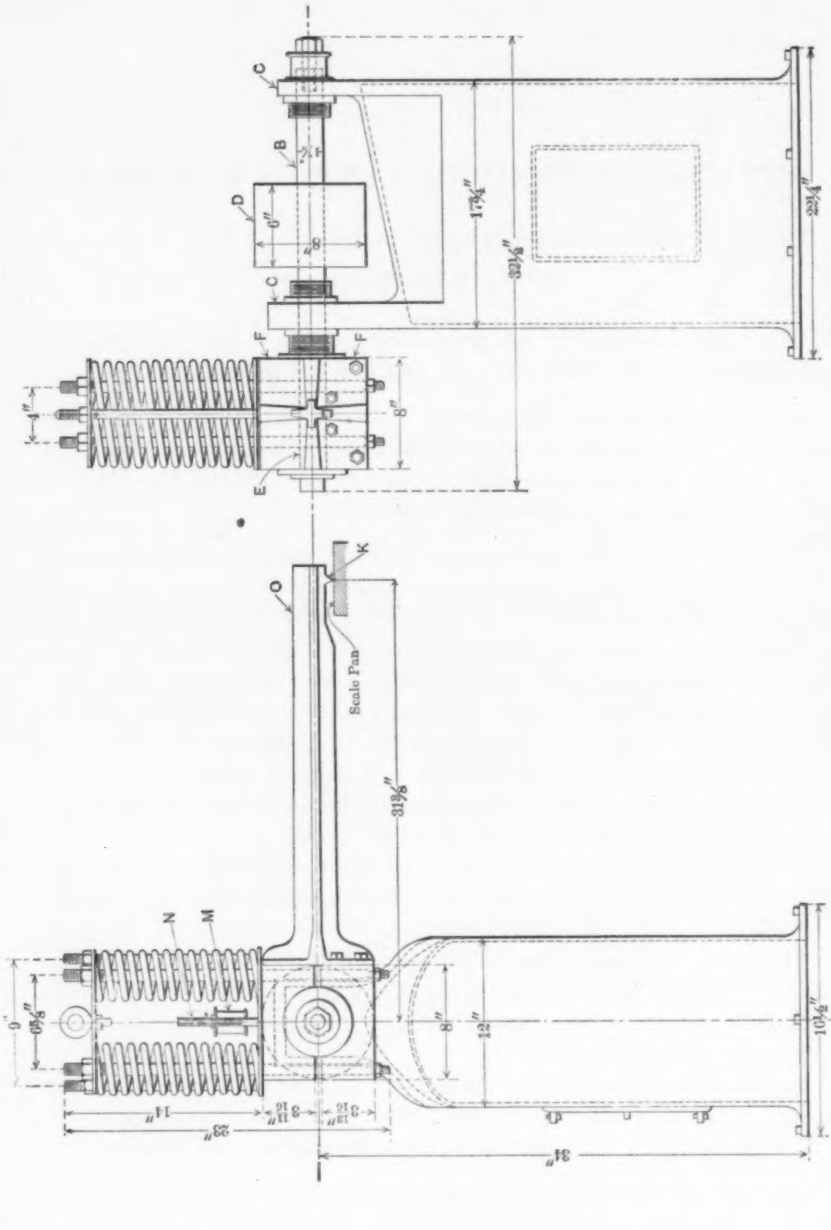

FIG. 1 APPARATUS USED FOR TESTING THE EFFICIENCY OF LUBRICATING OIL

is 8 in. long and 3.22 in. in diameter. Around the journal fits a babbitted sleeve, which is split in the middle, the upper half having oil grooves diagonally across it and intersecting in the middle in the form of a letter X. At the intersection of these grooves is the hole for the admission of oil. The lower half of the sleeve is without oil grooves. The sleeves are held in position on the journal by the cast-iron blocks *FF*. A collar at the back, next to the bearing *C*, and a washer and nut in front, prevent an endwise motion of the collar and sleeves, while allowing free rotation. The load is applied to both sides of the journal at the same time by compressing the springs when the nuts at the top of the springs are screwed up. Under ordinary working conditions the load is applied to but one side of the journal. These experiments therefore do not conform to actual conditions of pressure and wear, but as the results are comparative they are as fair to one oil as another in this respect.

5 The springs were calibrated before the tests by compressing them to a length of 11½ in., observing the load and then making this length the same for all the tests. The lever arm *O* was fastened to the upper block and its outer end was fitted with a knife edge which rested on a scale pan. The lubricant was fed through a sight-feed oil cup at *M*. The temperature of the bearing was determined by means of a thermometer inserted in an oil well at *N*. The machine was driven by an electric motor and the speed kept practically constant at 500 r.p.m. by means of a water rheostat.

6 The tests were conducted as follows, great care being taken to keep the conditions as nearly constant as possible for all the oils: The journal and sleeve were first cleaned with coal oil (kerosene) and rubbed dry with waste. The machine was then put together and the factor known in these tests as the lever-arm constant was determined. This was found by resting the knife edge *K* on the scale pan and rotating the journal first to the right and then to the left with no compression in the springs. The average of these readings gave the constant weight of the arm on the scales. Then the frictional resistance of the machine at any instant was measured by the difference between the scale reading at that instant and the lever-arm constant. After the constant had been determined the springs were screwed down to a length of 11½ in., giving a load of 1302 lb. for the whole bearing.

7 The oil cup was partly filled and the oil kept at a constant level so as to regulate the flow to a constant value of eight drops a minute. The machine was then started, and the bearing tempera-

ture, room temperature and scale reading were observed every ten minutes and the results entered on the log sheet of the tests. The oil feed and the speed of the machine were also adjusted from time to time and kept practically constant. At the end of two hours the oil supply was shut off and the run continued under the same conditions until the friction and temperature of the bearing indicated that the oil had given out.

8 The results of the tests are shown graphically by the diagrams in Figs. 2, 3 and 4. The horizontal scale shows the time in hours from beginning to end of test. The full lines were found by taking the bearing temperature on the vertical scale and the dotted lines were plotted by using the coefficient of friction on the vertical scale. The chart therefore shows the temperature, coefficient of friction and wearing qualities of every oil tested.

9 The coefficient of friction from which the dotted lines were plotted = journal friction ÷ load. For the machine used in these tests, this equation becomes

$$\text{Coefficient of friction} = \frac{(\text{scale reading} - \text{lever arm constant})\ \dfrac{\text{lever arm}}{\text{radius of journal}}}{\text{load}}$$

The scale reading is taken from the log sheets of the test.

The lever-arm constant was equal to 13.656 for this machine.

The length of the lever arm was 31.625 in.

The radius of the journal was 1.61 in.

The load on the journal was 1302 lb.

10 In the case of the castor oil, where the coefficient of friction at the end of two hours was 0.024 (see chart), by substituting in the above formula and transposing, we have:

$$\text{scale reading} = 0.024 \times 1302 \times \frac{1.61}{31.625} + 13.656 = 15.25$$

The scale reading being the known factor, the coefficient of friction was calculated for intervals of ten minutes corresponding to the time of the readings.

11 Table 1 gives the result of the chemical tests together with the data not found on the diagrams of Figs. 2, 3 and 4. The constituents of the oils, shown in Column 4, were found by distillation, each constiuent having a different temperature at which it separated from the oil. Nos. 1, 2 and 3 are simple oils; all the others

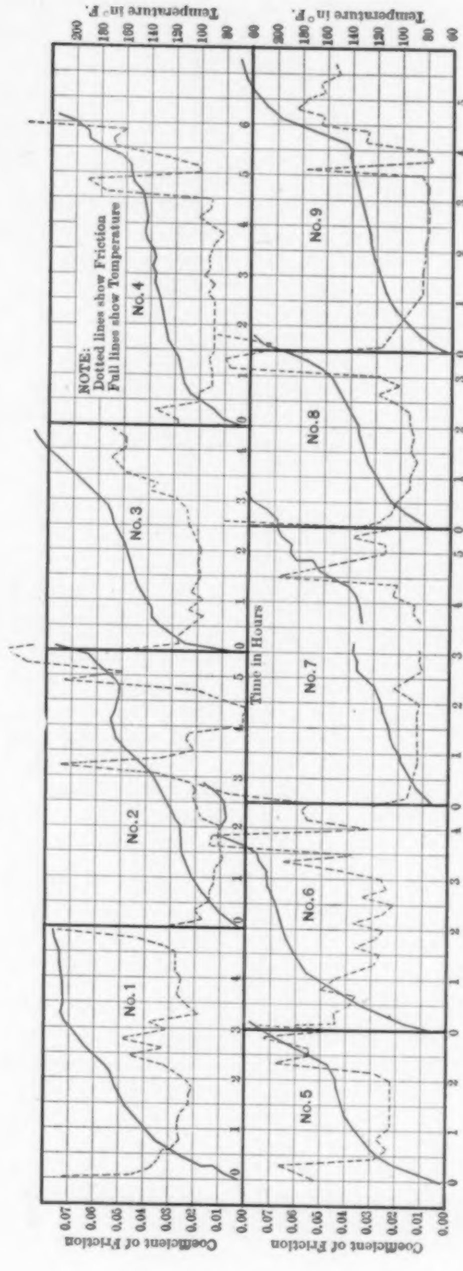

Fig. 2 Curves of Friction and Temperature obtained in Tests 1 to 9

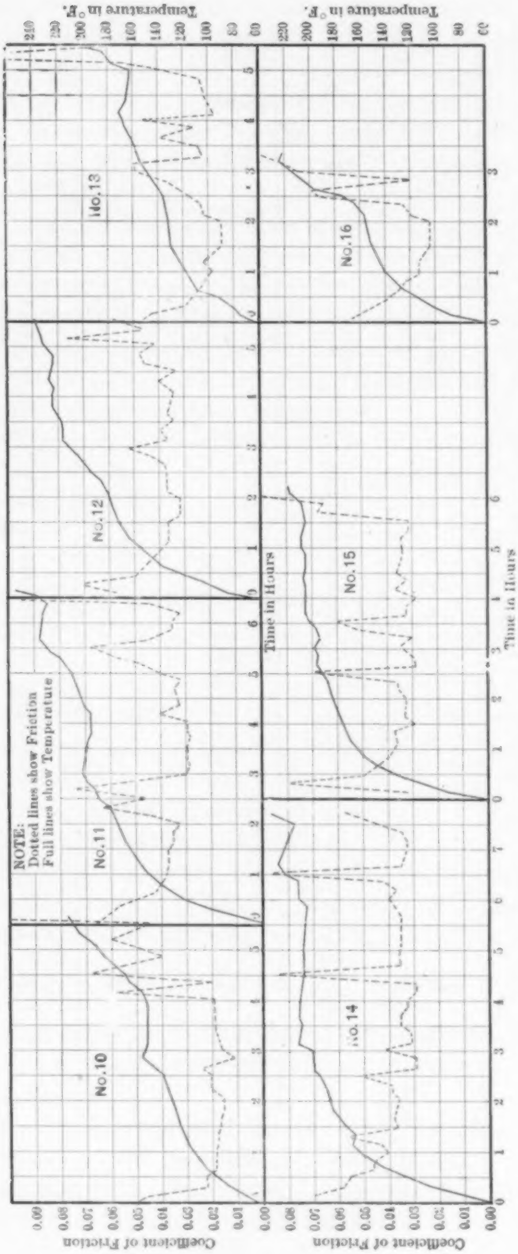

FIG. 3 CURVES OF FRICTION AND TEMPERATURE OBTAINED IN TESTS 10 TO 16

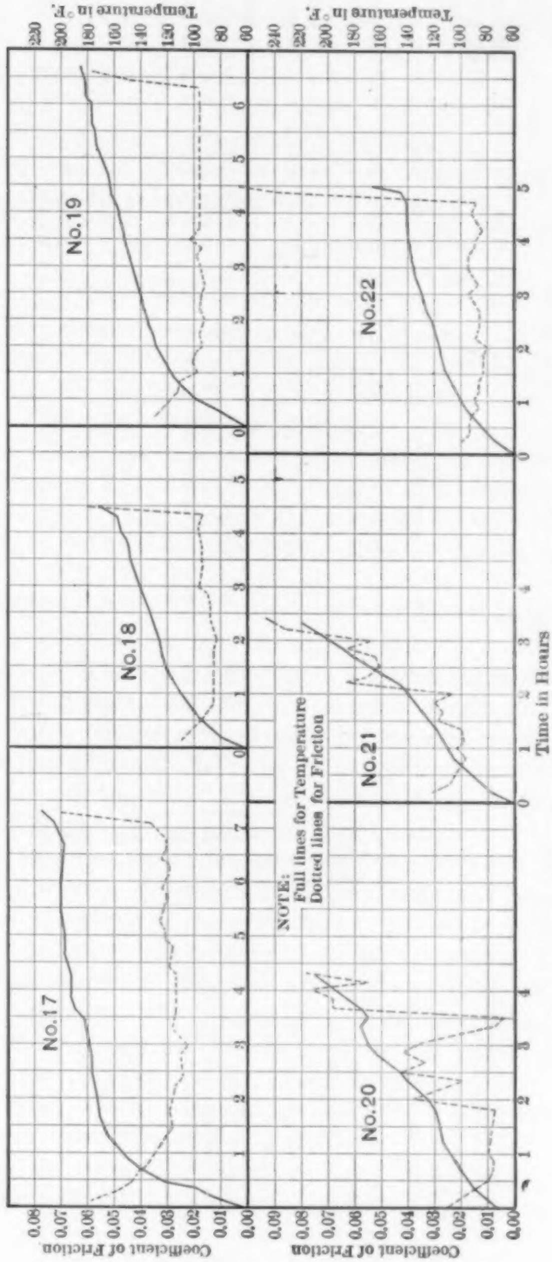

FIG. 4 CURVES OF FRICTION AND TEMPERATURE OBTAINED IN TESTS 17 TO 22

TABLE 1 CONSTITUENTS OF OILS AND DETAILS OF TESTS

No.	Kind of Oil[1]	Principal Constituents	Specific Gravity	Saponification Number	Viscosity	Flash	Fire	Oil Feed (8 drops per min.)			Endurance Test		
								Hours Feed	Max. Coef.	Max. Temp.	Hours Run	Max. Coef.	Max. Temp.
1	Pure castor (vegetable source)	....	15B	181	104 at 210°	.....	.....	2	0.0467	165	2.55	0.0740	215
2	Pure sperm (animal source)	....	30B	390	192 at 70°	.....	.....	2	0.0212	113	3.30	0.0960	214.5
3	Rape seed (vegetable source)	....	24B	324	108 at 150°	.....	.....	2	0.0278	154	2.24	0.0561	230
4	Engine No. 32789	Nos. 4 to 17 inclusive have for their principal constituents one of the four hydro-carbons C_nH_{2n+2}, C_nH_{2n}, C_nH_{2n-2}, C_nH_{2n-4}	26.6B	0	163 at 70°	378	432	2	0.0373	126	3.06	0.1109	212
5	Machine No. 32631		20B	0	472 at 70°	360	400	2	0.0656	146	1.10	0.1183	216
6	Capitol cyl. No. 32790		22B	10	123 at 212°	483	553	2	0.0496	186	2.50	0.0977	250
7	Dynamo No. 32,792		34B	0	86 at 70°	347	394	2	0.0156	111	2.55	0.1308	220
8	Union thread cutting No. 1		....	53	Low	200	230	2	0.0278	130	1.48	0.0920	216
9	No. 75		....	18		145	197	2	0.0335	121	3.12	0.0619	227
10	15° cold-test lub. No. 18		27B	18	480 at 70°	168	199	2	0.0457	129	3.35	0.0992	212
11	No. 74		....	25	....	267	318	2	0.0723	170	4.35	0.1260	250+
12	Model cyl. No. 14		28.6B	19	135 at 210°	258	310	2	0.0694	178	3.30	0.0741	236
13	Eldorado engine No. 37		....	.....	....	179	203	2	0.0429	129.5	3.27	0.1430	196
14	Filtered cyl. No. 72		29.6B	19	105 at 210°	246	284	2	0.0769	182	4.10	0.0902	218
15	Shield cyl. No. 6		28.6B	19	130 at 210°	178	309	2	0.0533	187.5	5.40	0.0826	232
16	Summer lub. No. 38		29.4B	19	120 at 250°	205	228	2	0.0515	152	1.30	0.0817	244
17	Amer. valve No. 17		27.6B	30	125 at 210°	285	382	2	0.0581	172	5.20	0.0704	214
18	Penn	$C_n H_{2n}$	0.861abs.	0	37.6 abs.	.....	.....	2	0.0241	126	2.30	0.0619	171
19	Penn	$C_n H_{2n-2}$	0.868abs.	0	87.4 abs.	.....	.....	2	0.0326	134.5	4.35	0.0581	184
20	Texas	$C_n H_{2n-4}$	0.923abs.	0	75.3 abs.	.....	.....	50m + 50m	0.0439	144	2.15	0.0855	228
21	Penn	$C_n H_{2n}$	0.850abs.	0	37.6 abs.	.....	.....	2	0.0297	140	1.20	0.0921	220
22	Penn	$C_n H_{2n}$	0.861abs.	0	37.6 abs.	.....	.....	2	0.1035	116	3.00	0.1039	165

[1] Nos. 4 to 17 inclusive are standard products made from Ohio and Pennsylvania products.

have for their principal constituent one of the group of hydrocarbons $C_n H_{2n-4}$, $C_n H_{2n-2}$, $C_n H_{2n}$, $C_n H_{2n+2}$. The purpose was to compare each oil having one of the above hydrocarbon radicals with the first three oils given, and thus to determine the relative effect of these hydrocarbon constituents.

12 The specific gravity is given in degrees Beaumé and is determined by the following formula:

$$\frac{130}{\text{specific gravity}} - 130 = \text{degrees Beaumé}$$

13 The viscosity was determined with a Saybolt viscosimeter. It is expressed in the number of drops per minute that will pass through a given orifice at a definite temperature. The table shows viscosities taken at varying temperatures. It is not practicable to take these viscosities all at the same temperature. The viscosity of an oil like No. 7, for example, if taken at a temperature of 210 deg. would not really represent the viscosity of that oil as it was never intended to be subjected to such a high temperature.

14 Column 5 gives the saponification number. This is the number of milligrams of KOH (potassium hydrate) that will be taken up by one gram of the oil. In other words, it is the number of milligrams of KOH per gram of oil that would be required to make soap. For example, in castor oil, which is a compound having a glycerine for a base, combined with a fatty acid, if KOH is added under the proper conditions, being a stronger base than the glycerine, it will drive out the latter and combine with the fatty acid in the proportion of 181 mg. to one gram of the original oil.

15 In an engine cylinder at a high pressure and temperature an oil may become decomposed, and the fatty acid being liberated will attack the metal of the cylinder. It follows therefore that the higher the saponification number of an oil, the greater the quantity of acid that may be liberated to attack the cylinder walls. It can hardly be said that the present tests show any definite relations between the viscosity and the bearing and lubricating qualities of the oils. They are interesting rather as showing the behavior of the particular oils in question in comparison with the relatively familiar examples numbered 1, 2 and 3.

16 The viscosity of an oil does affect its lubricating quality in the following way: if the oil is adapted to the load put upon it, then the lower the viscosity the better lubricant it will be. With heavy oils some work will be absorbed in overcoming the internal resistance

of the oil itself. The load should conform to the character of the oil, a light oil being unsuitable for a heavy load. The reason why some of the oils in these tests broke down early was because the load was too heavy for them.

17 Oil No. 21 contained paraffine and the injurious effect of this substance on the lubricating quality of the oil is shown by the chart for that oil. Oils No. 18, 19, 21 and 22 are individual hydrocarbons separated by long continued fractional distillation from Pennsylvania and Texas oils. These oils have been found to belong to the series $C_n H_{2n}$, $C_n H_{2n-2}$, $C_n H_{2n-4}$.

18 The series $C_n H_{2n}$ may be regarded as representing the larger portion of the constituents of lubricating oils as made from crude petroleum. The higher vicosity of these hydrocarbons, which are relatively poor in hydrogen, is shown in the table. Professor Mabery has been led to believe from his examination of different varieties of petroleum and the separation of individual hydrocarbons, that in oils like those of Nos. 4 to 17 of the table the general composition is represented by the series $C_n H_{2n}$, $C_n H_{2n-2}$. They also doubtless contain smaller amounts of hydrocarbon poorer in hydrogen.

19 The chemical work of the tests was done under the direction of Prof. C. F. Mabery and the mechanical work by the writer and Mr. Horace Allen, a senior student at Case School.

ECONOMY OF THE ELECTRIC DRIVE IN THE MACHINE SHOP

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It is proposed to show in this paper the most salient points which affect the economy of the electric drive in the shop, and also, in a general way, the proper relation between the motor and the driven machine.

2 When the electric motor was first used in the shop, practically no other claim was made for it than that it saved power by obviating the losses in line and countershafts. Exaggerated statements were made of savings to be effected; and though it was proved later that many of these claims should be divided by a large factor, and that some should even be provided with the negative sign, these statements did a great deal of good by calling attention to the fact that great losses existed.

3 The writer knows of no way to determine the exact amount of these losses, but wishes to call attention to the fact that a method which has been employed quite frequently is entirely misleading. The method referred to is, to measure electrically or by indicator card the amount of power required to run all or a part of shop with and without machine load. The difference between the two readings is supposed to be the loss. That this is wrong becomes obvious as soon as one considers that the frictional load of every bearing changes with the amount of the load, and that the belt pull sets up bending and torsional strains in long lengths of shafting, which may cause losses much greater than the losses by journal friction.

4 The method of taking separate measurements of the work done by each machine individually, and totaling the result, is also wrong, as all machines do not require the maximum amount of power at the same time. To multiply the total by some fractional coefficient is merely a refined way of guessing. Statements have from

time to time appeared, as to the amount of saving effected by the substitution of motor drives for line-shaft drives, but never with the positive statement that at the same time other changes were not made which might have some effect on the situation. This absence of reliable data is apparent all over the field of this subject, and it will therefore be impossible to say beforehand with any fair degree of certainty how much, if anything, can be gained by the conversion of a shop from a shaft to motor drive. It will be possible, however, to indicate points which should be kept in mind, and which are the controlling factors.

5 Economy is the art of obtaining the greatest output with the smallest outlay. To strike a balance between these two elements, outlay and output, is the work of the industrial engineer. In a great many cases, perhaps in the majority, there are not sufficient data to enable him to do this; his work then becomes hazardous and is on a level with that of the prospector. Many reputations are based on a stroke of luck and many have been lost by a single wrong guess. On the other hand, many hundreds of thousands, or more likely, millions of dollars have been lost to shop owners by listening to the lure of the enthusiastic engineer with more faith than data.

POINTS TO BE CONSIDERED

6 In considering the economical features, when converting a shop from shaft to motor drive, the following points should be kept in mind:

- *a* The nature of the shop.
- *b* The possible economies which may be effected by the installation of electric drive.
- *c* The first cost of such an installation.
- *d* The cost of its upkeep.
- *e* The cost per unit of power.

Though these are the main points to be considered in a preliminary investigation, they are by no means the only ones. They are specially mentioned here because their contemplation will naturally lead to the consideration of other points as well.

7 As the electric drive for the machine shop alone will be considered here, it may seem that the nature of the shop might have been left out of consideration. In the great majority of cases, however, a machine shop is of a dual nature. A foundry or blacksmith shop, or perhaps, a plating shop is connected with the establishment; or

warehouse and yard service may form a considerable portion of the operations. The yard service of a plant may be of an elaborate nature, while the machining operations are of a simple nature. It may be that the machine-shop operations cannot be improved enough by the change to electric drive to warrant its installation, yet the gains to be made by converting yard cranes and other similar apparatus to electrically driven apparatus may be so great as to make it advisable to change the mode of driving of the entire plant.

8 As to the possible economies which may be effected by a change of drive, this involves so many considerations that nothing but an exhaustive study of the entire plant in all its aspects will clearly show what may be accomplished. Though at one time the only economy considered was the saving of power, it is now well recognized that this is by no means the only nor the most important economy resulting from a conversion to electric drive, and that such a conversion may even be highly economical, though there be an actual loss in power consumed.

9 To illustrate: practically all of the work done in a machine shop, for which power is used, is the removal of chips. The writer has in mind a shop where an average of 9 tons of metal is daily fed through the shop, to be made up into high-grade machinery. This metal is for the greater part cast iron, with a minority of steel and a small percentage of bronze and other metals, just as in most machine shops. The total of chips removed amounts to less than 15 per cent or 2700 lb. of metal in a nine-hour day, making 300 lb. per hr., or 5 lb. per min. This shop uses an average of 225 h.p., which is 45 h.p. per min. for each pound of chips removed. Figuring that all the chips are steel, this would mean that the shop requires about 12 h.p. per cu. in. of steel removed. It should be noted that this shop is to a large extent electrically driven, and otherwise as well or better equipped than the majority of machine shops. The power costs about $40 per h.p. per year, or a total of $9000, which includes steam for heating, however.

10 Figuring that all of this amount is spent for power, and that half of it could be saved by some other mode of driving, then the total possible gain would be $4500 per year. This shop employs about five hundred men, so that the gain would be $9 per man per year. An establishment of this kind and size delivers a product of about $2000 per man per year. If the installation of a new mode of driving could increase this output only 5 per cent, then the gain per man per year would be $40, or more than four times the gain which

can be made by cutting the power consumption in two. Obviously then, the problem is to increase the amount of chips made in a given shop, and not to diminish the amount of horsepower for a given amount of chips. This phase of the subject will be treated more extensively later.

11 As to the first cost of installation, though it may be beyond doubt that a change in the mode of driving might effect economies yet it remains to be shown that these economies give a good return on the investment, and further, that this same investment could not be placed in another direction to better advantage. What is true when a shop is to be converted from one drive to another, is also true when a new plant is to be built. Directors of industrial undertakings have frequently been criticised for apparent lack of progress, when a close analysis might have shown other more crying needs for the investment of the capital at command. Though the shop of an industrial undertaking may be the only place where its product is made, it may not be the only place where its money is made. And even should the shop be beyond doubt the best place to invest the money on hand, it remains to be shown that the proposed change of drive will bring better returns than improvements along other lines. This question will also be dealt with later.

12 The probable cost of upkeep must also be thoroughly investigated, especially as this is likely to be under-estimated unless one goes fully into details. In considering the probable economies, this cost of upkeep has to be estimated and deducted from the gross gains; but the same item appears again in the form of disturbance of operation, when it is much harder to estimate it. This must be done as well as possible, however, before reaching a final conclusion. These disturbances make themselves especially felt the first few years after making the change.

13 It is further true that most radical changes are made at a time when there is a heavy demand on the shop, either because it is thought that the output can be increased by the contemplated changes, or because the size of the power plant has not kept step with the growth of the rest of the plant, or because at such times of business prosperity, money can be easily obtained for such changes. Whatever the reasons, the fact has been fairly well established; and a change at such a time must be doubly hazardous, not only because it may fail to accomplish the desired increase of output, but because it may actually prove to be a source of disturbance, and reduce the output instead of increasing it.

14 As to the cost per unit of power, this should enter into the preliminary considerations, as it will determine to a large extent the kind of current to be used, and this may have a decided effect on the final economy of the system as applied to the shop. Attention will again be directed to the foregoing items later in the paper.

SAVINGS EFFECTED BY ELECTRIC DRIVE—INCREASED OUTPUT

15 The savings effected by driving the shop electrically may be classed under two heads: increased output and less expense. Whether savings can be effected by increasing the output depends on so many and such varied items that it seems best to show them first in an elementary way, by considering a single machine under a set of assumed conditions.

16 Let us take for example a 12-ft. boring and turning mill, used in a shop devoted to the manufacture of a single line of product and having enough machines of each kind to allow each machine to be devoted to a very limited line of operations. Suppose the machine under consideration to do nothing but turn up large rings, ranging in diameter from 12 ft. to 8 ft., and further, that a great number of rings of each size are to be turned up in each lot, so that the amount of time lost in setting the machine for the different kinds of work becomes negligible. Let it be further supposed that the machine is provided with a number of speeds in geometrical progression, with steps of 25 per cent, and that there is one speed which happens to correspond to the proper speed for the material used and for a diameter of 12 ft. This is supposing a set of conditions as good as can be expected in the ordinary commercial machine.

17 Under these conditions, the low speed must be used for all rings from 12 ft. down to 9.6 ft., and the next higher speed for all rings ranging from 9.6 ft. down to 8 ft. Supposing that the number of all rings of the same size is the same, it follows that the machine runs $\frac{6}{10}$ of the year on the lower speed, and $\frac{4}{10}$ of the year on the higher one. Allowing $\frac{1}{4}$ of the total time for chucking work, removing it, changing tools, etc., there remains $\frac{3}{4}$ of the year spent in removing chips. The machine removes chips, therefore, at the lower speed during $\frac{9}{20}$ ($\frac{6}{10}$ of $\frac{3}{4}$) of the year, and $\frac{6}{20}$ ($\frac{4}{10}$ of $\frac{3}{4}$) of the year at the higher speed. This higher speed might be called 12, and the lower speed 9.6. A measure for the amount of chips removed, and, therefore, for the number of pieces turned up, would then be the amount of time multiplied by the linear speed of the tool. This is not exactly correct, but near enough for a mere illustration.

18 So far, however, an expression has been found only for the number of revolutions of the machine. In order to reduce this to linear speed, we must consider the fact that the higher speed is the proper speed for a diameter of 9.6 ft., and the lower speed for a diameter of 12 ft. If the machine were to run all the time at the speed corresponding to the diameter to be turned up, the total output for the year could be expressed by the time the machine is actually removing chips, which is $\frac{3}{4}$.

19 When running at the lower speed, however, the machine has the proper speed only when the diameter to be turned up is exactly 12 ft. At all other diameters, the speed is too low. The effect is the same as if the machine were running all the time at the lower speed, and all the work were of a diameter of the mean between 12 and 9.6, or 10.8. Therefore, when running on the low speed, the output runs down from $\frac{9}{20}$ to $\frac{81}{200}$. Similarly, the output of the machine, when running at the higher speed, has been reduced from $\frac{6}{20}$ to $\frac{55}{200}$, and the total from $\frac{3}{4}$ to $\frac{136}{200}$, or a reduction of nearly 10 per cent. Now if this machine were driven by a variable-speed motor, it would be possible to find a proper speed for every size of ring to be turned up, and the production might be increased from 136 to 150, or a gain of nearly 11 per cent.

20 Merely to say that there is a gain in production of 11 per cent is perhaps sufficient to prove that under certain conditions a change from belt to motor drive may be profitable, but it is in no way a measure of the amount of profit. If, for instance, the machine is capable of taking care of all the work in the shop, then the only gain is in the wages of the operator; if, on the other hand, there is more work than the machine can take care of, then the increased production of the machine may mean a corresponding increase in the production of the entire shop, improved deliveries, and the avoidance of a great deal of confusion, of which the money value may be many times greater than the mere saving in wages.

21 In the foregoing example, the advantage gained is entirely due to the fact that a variable-speed motor was attached to the machine. This is by no means, however, the only reason why the change to electric drive may increase the efficiency of a machine. The electric drive may enable one to place the machine in a more convenient position, or bring it under a crane; or it may be the means of giving the machine more power than it could have with a belt drive; or again, it may be the means of doing away with some harmful conditions which have diminished the machine's efficiency.

Among such circumstances may be mentioned the slackness of belts due to weather conditions, or to the varying loads placed on an upper floor, making the belts from pulleys attached to the under-side of this floor either too loose, having been adjusted at a time when the load on the upper floor was light; or too tight, owing to adjustment at a time when the load on the upper floor was heavy. Then there is the convenience of altering speed if a machine has a motor or a convenient gear drive, when the operator might forget that there is such a thing as a change of speed for varying conditions of work, if he had to shift a belt. An almost unlimited number of considerations affect the result to be obtained from the application of a motor to a machine tool; so that it is almost impossible to forecast the economy which will result from such a change, though it may be perfectly possible to say that the change will be beneficial to some extent.

22 The fact that the change from one style of drive to another is practically always accompanied by some other changes, either in addition to, or as a result of the change of drive, makes it impossible to show by data how much gain is the result of this change. Under very definite conditions, such as were supposed in the example given, it may be possible to calculate these gains beforehand, and even to verify the calculations by the actual results, but in the vast majority of cases neither calculation nor verification is possible. For this reason, this paper is confined to pointing out in which respects, and under which conditions profits may be expected. Such profits will appear either in increased output or in the curtailing of expenses.

HOW ELECTRIC DRIVE EFFECTS INCREASED OUTPUT

23 We will now consider more in detail the economic advantages mentioned in the foregoing paragraphs. Fig. 1 shows the main points in which an increase in output may be expected from the substitution of electric drive for shaft drive. The electric drive will show its effect on individual machines (provided they are individually motor-driven), on the handling of the work in the shop, on the light and cleanliness of the place, on the possibility of making changes in the arrangement of the shop when needed, and last, but not least, on the individual effort of the operator.

24 *More power.* The greater output of individually motor-driven machine tools is due to a number of items, shown in the diagram. The first item, more power, is especially prominent in heavy tools.

The power of cone-driven machines is limited by the belt speed, and by the width possible, considering that the belt has to be shifted. It might be said that a single-pulley drive has no such limitations; but on the other hand the single-pulley drive does not lend itself to fine gradations of speed, especially in heavy machinery. Further, such a drive would take up a great deal of space, would be very costly, and would be extremely awkward to handle, unless auxiliary mechanism were provided to do the shifting of the heavy gears, which is

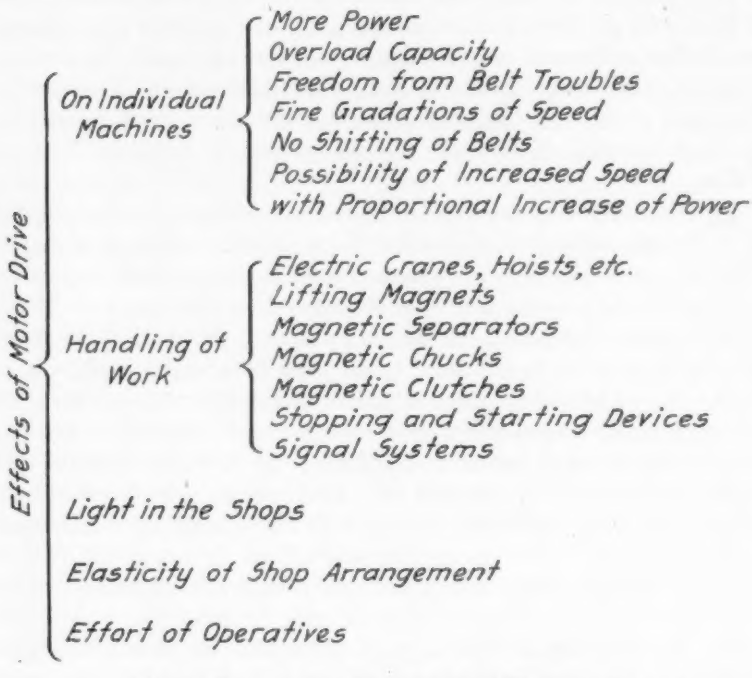


Fig. 1 Showing the Advantages of Electric Drive

a further source of expense. The electric drive, on the other hand, would allow of a motor with a certain amount of variation of speed, which, combined with a few gears, would give all the variation obtainable with the cone pulley, and by much finer gradations. This is so well recognized at the present time, that very few heavy machines are built to order with a cone drive.

25 High-speed steels made an increase of power imperative for some of the heavy machines, and for some of the lighter ones as well.

In a number of cases, it was found that the frame of the machine, as well as most of its mechanism, was strong enough to stand this increase of power, but that it was practically impossible to substitute larger cone pulleys without rebuilding the entire machine; in all such cases, the electric motor has proved to be the solution of the problem.

26 *Overload Capacity.* The electric motor not only makes it possible to give more power to the machine, but it gives it a reserve capacity that a belt-driven machine cannot have. For instance, a casting has to be turned up: it has a swelling where the seam of the parting is, and the amount of metal at this one point is too much for a single cut; the machine stalls. If the machine were motor-driven the overload capacity of the motor would carry the cut past this point, without harming the motor. In other words, a motor acts on a machine tool somewhat as a flywheel acts on an engine. Before electric drives were known, the power of the machine tool was almost always its weak point; after electric motors were applied to existing machines, it was the frame of the machine which had to be treated with consideration.

27 *Freedom from belt troubles.* The omission of belt troubles is one of the strongest points in favor of the electric drive. During an investigation of a large Western railroad shop by the writer, this point was shown with exceptional clearness. Practically all machine operators "nursed" their jobs because they had to wait too long for the chief millwright, who thought he was the only man capable of putting on or correcting a belt in the proper manner. Out of consideration for the machine tools, this man would put on belts from ½ in. to 1 in. too narrow. The combination of these two pieces of foolishness reduced the output of the belt-driven machines fully 50 per cent where heavy cuts had to be taken, and reduced the output of the entire machine department at least 10 per cent. It might be said that the management should have corrected this evil, and so it did, but only after the evil had existed for a great many years. Conditions such as these are the outcome of growth, and are generally not found out until the shop becomes too small for the work to be done and the management begins to cast around for means to increase the output.

28 Belt troubles are caused by so many conditions that a shop is rarely free from them. It was observed at the shops of a machine-tool concern in the middle West, that the output of their milling machines was increased 25 per cent by driving them by electric motors, though no further changes were made. The observation

deserves attention, because while some of the machines were changed to electric drive, other similar machines were left with belt drive, and there is a clear chance for comparison. The main reason for the increased output was supposed to be the avoidance of belt trouble. These milling machines were located on the first floor. The second floor was also used for a machine shop, and was at times heavily loaded with finished and unfinished stock; this variation in loading causing a variation in the deflection of the upper floor, that made it necessary to keep the belt quite slack, for fear it might be too tight when the upper floor was not loaded. Weather conditions have a similar effect; especially where there are rapid changes in humidity. The effect is to lower the capacity of the machine by a large percentage.

29 *Fine gradations of speed.* Another reason for the greater economy of motor-driven machines is that finer gradations are obtainable with a motor drive. Of course, this benefit is derived only from a variable-speed motor. When attention was called to this feature earlier in the paper, nothing was taken into consideration except the fact that it would be possible with the variable-speed motor to obtain a speed in accordance with the material to be cut, and with the diameter of the work or of the cutter. However, there is more than this to be considered. A lot of castings are seldom or never of uniform hardness. This being the case, it is quite natural for the operator to set his machine for the hardest piece in the lot, and it may well happen that he strikes the hardest piece first. Where he has simple means for varying his speed, he will be governed entirely by the hardness of the piece on which he is doing work.

30 *No shifting of belts.* The fact that no belts have to be shifted is another cause of increased efficiency. The machine operator who shifts belts for pleasure has yet to be found. Besides, where the ceiling is high, it is not easily possible to shift a belt without the aid of a long stick; and this stick is generally somewhere else. The amount of time lost in hunting for the stick, and in the operation of shifting the belt, may be quite considerable in itself, especially in shops where small lots are the rule and where it does not pay to perform only one operation at a time, so that a single piece must receive all the operations of a certain machine before it is taken out of it.

31 But worse than the loss of time in shifting belts is the fact that this shifting is generally entirely neglected, and all the various operations are carried out at the speed of the slowest. There are cases

where the gain due to this feature of the motor drive may be negligible, and there are other cases where this gain may be a large percentage.

32 *Increase in power with increase in speed.* Another point in favor of the motor drive, is the fact that it is possible to speed up a machine with a proportional increase in its power. This problem appears whenever a change is made from carbon to high-speed steels; and though most shops at the present time are provided with high-speed cutting tools, this is by no means true to such an extent that this point may be overlooked. There are few, if any shops where some operations are not done with carbon-steel tools, sometimes because high-speed steel has been overlooked, but more often because no benefits would be derived from it as the machine could not be run at a higher speed without cutting down the depth of cut or feed. In some cases, this can be corrected by putting a larger pulley on the line shaft; but in the majority of cases which have come to the attention of the writer, this could not be done without more elaborate changes.

33 Generally speaking, it is a small thing to increase the speed of a motor-driven tool without cutting down its torque. Not long ago a number of cases came to the attention of the writer, which put this matter to him in a very clear light. Some boring machines, used for boring holes out of the solid in steel bars, and using twist drills for this purpose, were supplied with high-speed drills; but it was found that the feed could not be increased, as the machine was run to the limit of its capacity. It was further found impossible to shift the belt to a larger step of the cone, thus giving more torque, as it was not practical to increase the speed of the machine without making extensive changes in the arrangement of the line shaft. A motor drive would have solved the problem and would have increased the feed from $\frac{5}{8}$ in. to $1\frac{1}{8}$ in. per minute. Such instances are by no means rare. It is this feature of the motor drive which makes it possible, in many cases, to get the full benefit of high-speed steels with old machines.

HANDLING OF THE WORK

34 *Electric cranes.* Electric current in a shop not only makes it possible to get more production from machines individually, but admits of a number of improvements in the handling of work. The electric traveling crane has become such a common aid in the shop that it is almost difficult to realize that it is only twenty years since it was new. It is also hard to realize that it is one of the possibilities

of the electric drive. The effect of the electric crane on the economy of the shop cannot well be over-estimated; though it is difficult to express in figures the amount of this economy. So much can be said, that only a few shops are over-supplied with cranes, while in a great number more cranes could be placed to good advantage. The installation of electric cranes or hoists in a shop is somewhat similar to the installation of compressed air. It is generally difficult to estimate beforehand with certainty the amount of savings to be effected, or to realize the various uses to which the apparatus will be put, but once a compressor is installed its capacity is soon exceeded; similarly, the electric crane is soon overworked.

35 The proper choice and installation of electric cranes and hoists is a separate branch of industrial engineering, though not generally considered as such. The best effects can be had only when the apparatus is taken into consideration with the placing of the tools in the shop, and the laying out of the shop buildings. Instances where the exact amount of savings effected was known even after the new apparatus had been installed for some time, are also rare, though not quite to the same extent as data about machine tools. The installation of a yard crane in a flask yard reduced the number of laborers from nine men to two and the crane tender. The installation of a small electric hoist, on a small traveler worked by hand, increased the output of a milling machine, besides doing away with the help of a laborer. It should be remarked here that the weight of the piece to be milled was too much to be lifted by hand, and that the time used for the operation proper was small. Instances of this kind are not rare and have come under the observation of almost any engineer connected with industrial establishments.

36 *Lifting magnets.* In line with electric cranes are lifting magnets, which are to be considered as an adjunct to the crane. They can often be used to good advantage for lifting plates, for loading and unloading pig-iron and scrap, for hauling small castings in quantities, and even larger castings provided their shape and the distribution of metal makes them adapted to this mode of handling, for lifting drop weights, and for a number of other purposes. Though no instances are at hand, it seems to the writer that a small lifting magnet could be used to good advantage for collecting chips at the various machine tools in a shop.

37 *Magnetic separators.* Magnetic separators, though more commonly used in the foundry, are used also in the machine shop for the complete separation of the chips of various metals. However,

they seem to be more in the nature of a luxury than of a necessity.

38 *Magnetic chucks.* This cannot be said of magnetic chucks, which make it possible to do quickly, conveniently and accurately a great many jobs which would be very difficult, if not impossible, without this piece of apparatus. Magnetic chucks are of special merit in combination with small planers, shapers, milling machines, lathes and grinders. Their economical value may range from a mere aid to the operator, to the means of doing a job which could not otherwise be done at all. It is generally easy to estimate the savings to be effected, as the time for ordinary chucking methods is well known, and the time for chucking by means of the magnetic chuck, is practically negligible; further, the amount of power used for the chucks does not need to be taken into consideration. They have their limitations and are not adapted to all or even to a great number of operations; but where they are applicable at all, they are of great value.

39 *Magnetic clutches.* Magnetic clutches seemed at one time destined to play a great part in shop economy. So far, however, they have been a disappointment. This seems to be partly due to inherent weaknesses of the magnetic clutch, but perhaps more to faulty construction, and especially to the fact that those who designed and developed the magnetic clutch did not quite clearly understand the requirements of the machine tools to which they were to be applied, and further, that those who had to apply the clutch to machine tools did not understand the peculiarities of a magnet. There never was the hearty coöperation that would make the magnetic clutch a success.

40 It would not be surprising to see the magnetic clutch come to the foreground once more and claim its own. There seems to be a field for this kind of apparatus in controlling mechanism of all kinds, as well as for braking the movement of a machine or a part thereof. Its peculiar value in this respect would be to give the operator the means for controlling his machine, by merely touching a button or turning a small switch. The magnetic brake is employed now, especially in cranes, indicating that there is nothing inherent in the magnetic clutch which makes it unfit for application.

41 Attention might be called here to the possibilities of the application of the magnet in its various forms to operations in the shop, and to functions in a machine tool. Magnets now are employed for holding small portable tools in position, and might be used for

vises and other handling devices. Further attention should be called to the possibility of using the motor itself as a brake, by short-circuiting the armature on a given amount of resistance.

42 *Stopping and starting devices.* In the previous paragraphs, mention was made of the possibility of applying the electric magnet for the purpose of controlling a machine. This might be called control from a distance though in the applications hinted at, the distance would be very small in most cases. There is no reason, however, why this distance could not be increased at will. As a matter of fact, a number of installations are in existence where electric devices (though not necessarily electro-magnets) are in use for this very purpose. They will be found especially in rolling mills, and other plants where given amounts of material have to be handled continuously. These devices enable the engineer to minimize manual labor, besides making the plant safer and the action more continuous.

43 *Electric signals.* Electric signal service in shops was well known before the electric drive was thought of, but it can be greatly improved where electric power is at hand, as lamps of different colors, placed in the shop, will transmit intelligence better and with less confusion than electric bells. The telephone would come under the head of electric signals, but it is not dependent on the use of current in the shop.

44 *Lighting.* One of the greatest blessings of the electric current in the shop is electric lighting. This is so generally acknowledged, and so universally employed, however, that it would be a waste of space to go further into this matter here.

45 *Elasticity of shop arrangement.* Another great benefit of the electric drive is elasticity of shop arrangement. Growing establishments had to be satisfied with arrangements of machinery which had no other point in their favor than that they were the only possible ones. It was often necessary to place departments where they should not be, simply because it was not possible to drive the machinery in them if they were placed elsewhere. The electric drive makes it possible to change the arrangement of the machinery, and the relative location and size of the different departments, according to the changing needs of the shop. This principle of changing the shop according to the work to be done, is carried to its logical limit in the system of floor-plates and portable tools.

46 Besides making alterations in an existing arrangement possible, the electric drive also allows departments to be placed far

enough from each other to permit of extending each one separately, without interfering with the other departments. This was generally not possible with belt drive, as the distances became entirely too large. It was generally found necessary for large plants to have a multiplicity of engines. A number of the best known modern shops are witnesses to the advantage of electric drive in the matter of arranging buildings and departments. It is hardly necessary to mention that the established ideas in regard to shop arrangement had to be largely revised and that there is even now considerable uncertainty as to what is the best possible arrangement, but it is safe to say that there is little divergence of opinion as to what kind of drive will give the greatest possible elasticity, if elasticity is required or deemed advisable.

47 *Effect on operatives.* It was mentioned before that the variable-speed motor, applied to a machine tool induces the operator to experiment with the best possible speeds. There is, however, another way in which the electric drive affects the efforts of the men. It is nowadays well recognized that favorable conditions in regard to light, heat, sanitary conditions, etc., have their immediate effect on the output of the shop. These conditions cannot be ideal with a confusion of belts obstructing light and gathering and distributing dirt. Though in most electrically driven shops belts are not entirely absent, they are so few that their evil effects are reduced to a minimum.

RELATION OF FIRST COST TO DECREASED EXPENSES

48 Whether savings are effected by lessening expenses depends on the nature of the old installation and that of the new one.

49 The writer was at one time connected with a large manufacturing plant, spread over a large tract of ground, which in its general layout and operations is fairly representative of a great number of existing manufacturing plants. It was at that time steam-driven, as the motor had not been sufficiently developed for a complete electrical drive to be considered. However, the management being progressive, partial conversion to electric drive was considered even at that time. The plant included two multiple-story buildings used as machine and erecting shops, a forging shop, a building used for some machine operations, for dropping malleable castings and for a warehouse, a wood-working shop and warehouse, another warehouse, and a malleable and a grey iron casting foundry. There were in all five engines driving these different shops, with the necessary trans-

missions from one building to another. In a few cases, quite elaborate systems of shafting were installed to drive a single piece of machinery; such, for instance, as the elevator in the warehouse. The engines ranged from 150 to 500-h.p. It was not possible at that time to determine accurately the aggregate of power consumed in that plant, but it was estimated that a single 1500-h.p. engine would carry the entire load. In the light of later developments, this amount now seems excessive, as a number of shops have since found that the amount of loss by friction in the transmission is greater than what was estimated at that time, namely 30 per cent. The single engine could have been run condensing, as plenty of water was at hand. The several smaller engines did not pay, of course.

50 The following items would have decreased expenses, if this plant had been driven electrically:

a Lower first cost of engines.
b Lower first cost of boilers.
c Lower cost of piping.
d Lower cost of power houses.
e Lower cost of stacks.
f The omission of all transmission machinery.
g Greater economy of the engine in its steam consumption.
h Economy in oil and waste.
i Economy in repairs.
j Reduction in the number of engineers required.
k Reduction in the number of firemen required.
l Saving in the handling of coal and ashes.
m A probable more even load during the day, as the greater number of machines on a single engine has a tendency to equalize the load.

51 A number of these points are of value when a power plant is newly built, but are of no value where an established power plant is to be changed. To offset the above items the following must be considered:

a Greater first cost due to the generators.
b Greater first cost due to the wiring.
c Greater first cost due to the motors.

52 Besides, there are a great number of other factors to be considered. In this plant there were no duplicate engines, so that it would not be fair to figure in the first cost of the electrical installa-

tion of a reserve unit; though, of course, good present-day engineering would consider this an absolute necessity. It is true that where there are a number of engines, the breaking down of a single engine does not throw the entire plant out of action; but it is also true that in the plant under consideration the stoppage of a single department would soon have closed the entire plant. Considerations of this kind cannot be generalized, but must be taken up in detail in every specific case.

53 Another point to be kept in mind is, that copper wire largely takes the place of transmission machinery, and that such wire is an asset with practically no depreciation except that due to fluctuation in price (and this may be up as well as downward). On the contrary, transmission machinery should be considered as an expense, as in most cases it has no value except as scrap iron when no longer in use.

COST OF UP-KEEP

54 Still another point, and one which should have most careful consideration, is the value of the time of the plant, and the relative chances of a breakdown. In some plants the process is continuous: that is, the product goes from one machine to another without interruption, and the breakdown of a single machine would cause the stoppage of the entire plant. In such cases the breakdown should be charged with the amount of the productive capacity of the entire plant during all of the time lost. In other plants the various machines balance each other only roughly and often there is a small surplus of almost all kinds of machines in use, while some of the machinery is used only part of the time. Where these conditions prevail, the loss due to a breakdown of a single machine may be simply the cost of repairing the apparatus. In a majority of cases, neither of these two extremes is the true condition, and the engineer considering the kind of drive to be used must make some estimate of the loss due to a breakdown in any part of the installation. It should be kept in mind that the correctness of his estimate can never be established by positive proof; for, no matter which course he takes, it is impossible to say positively what would have been the result if he had pursued the other.

55 Though all of the points mentioned above affect the ultimate economy of the power installation, their relative importance changes with local conditions. For example, while the saving in the coal bill may be of the greatest importance where coal is high-priced and where

the expenses for power are a large portion of the total expenses, this saving may be a vanishing quantity where coal is cheap, and where the expenses for power form but a small fraction of the total expenses of the plant.

56 While in the example cited there was a decided saving in the number of engineers required there may still have been a loss on this score, due to the fact that in some small plants a high-grade engineer must be employed for an electrical installation, whereas a combination engineer and fireman would be good enough for the engine-driven proposition. And so on all along the line: what is a saving in one case may be a loss in another.

COST OF UNIT POWER

57 In practically all cases which have come to the notice of the writer, the cost of power per unit has gone down after conversion to electric drive, but in no case was it possible to point out in what way the saving was effected, as in addition to the substitution of electric drive for shaft transmission there were always other changes which might affect the cost of the power. Such changes were, more efficient engines, better boilers, new auxiliary devices, etc. Also in all these cases, the amount of power required after the conversion was greater than before: but this was not proof that the new installation was less effective than the old one, however, the probable cause in all these cases being that the output of the shop increased much more than the amount of power saved would have taken care of. It is almost to be regretted that high-speed steels made their entrance into the shop almost simultaneously with the electric drive. Though both are good, they have obscured each other to such an extent that it is almost impossible to trace the effects of each item separately.

CHOICE OF THE ELECTRIC SYSTEM

58 If, after considering all these points in a general way, the engineer comes to the conclusion that the electric drive will decrease expenses, then the next step will be to select the nature of the drive. The diagram in Fig. 2 shows the main points to be considered.

59 Whether a central generating station or a multiplicity of smaller plants is preferable, depends again on local conditions. Certain conditions might make a number of generating plants preferable, as for example, in a plant which consists mainly of a machine

shop requiring considerable power, with a smaller wood-working shop located at a considerable distance from the rest of the plant. In this case, the outlay for copper to supply the wood-working shop with power would be considerable; whereas, by placing an individual generating plant near the wood-working shop, the shavings might be used instead of coal.

60 Another case would be where a portion of the shop requires a great amount of power, but only for a short time each day, or perhaps at long intervals, thus necessitating a large outlay in generating machinery and copper. By separating this plant, the outlay for copper is avoided and a cheaper class of generating machinery may be used.

61 The writer has in mind a plant devoted to the making of electric generators and motors. By far the greater part of its output is in

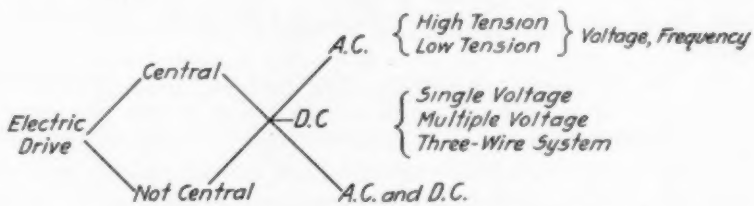


FIG. 2 SHOWING THE DIVISIONS OF ELECTRIC DRIVE

smaller units, but a certain small percentage is in larger generating units. The power required for testing these large generators exceeds in amount all the power required for the entire plant. This plant gets its current from a central station near by, but the amount of copper required for the large testing currents would be more than the cost of installation of a cheap gas engine and generator. Here again the engineer must consider conditions as he finds them and must not be governed by general principles only.

ALTERNATING OR DIRECT CURRENT

62 The question whether alternating or direct current should be used is especially difficult of solution, and there is a wide difference of opinion among engineers as to which is best. It way be that too many engineers look at this proposition only from a power standpoint, without giving due attention to the output of the plant. Commercial reasons also have figured largely in the past, the representatives of

companies manufacturing both kinds of apparatus naturally advocating the alternating variety, as by so doing they eliminated some competition. Now that more electrical companies manufacture alternating apparatus, this phase of the matter has almost entirely disappeared

63 *Alternating current.* It may be said that, all other conditions being the same, alternating current offers an advantage when the distances over which the current must be transmitted are considerable. The fact that current can be generated at high voltage diminishes the amount of copper needed for transmission, but here again the problem is not simple. Attention must be paid to the expenses incurred in step-up and step-down transformers and auxiliary apparatus; and also to the fact that money invested in copper conductors is lost only in part, while money invested in auxiliary apparatus is lost almost entirely in case of a change. There are a number of cases where the installation of alternating current would be the only practical solution, on account of the long distances and the heavy currents to be carried.

64 The advantages of alternating current, as well as its disadvantages, are well understood, and it is unnecessary to call attention to these points. It may be well, however, to point out instances where it is easy to make a choice. Given a plant covering a large area and using large amounts of current, of which only a small portion is used for variable-speed machinery, and of sufficient size to permit of the use of a separate unit for lighting current, and alternating current would be the logical solution. On the other hand, given a compact plant, using a large portion of the power for variable-speed machinery, direct-driven by motors, and of which the lighting load is small in the daytime, and it would be natural to select direct current. As a rule, however, conditions are not so simple, and it is generally very difficult to prophesy which system will give the best results. Of late the problem has been complicated by the fact that a great many machine tools may be had with single-pulley drive, to which an alternating-current or a direct-current motor is equally applicable.

65 *Alternating-current motors.* The points in favor of the alternating-current motor are then:

a High breakdown point; that is, the motor goes on with no material change in speed under very heavy overload.

b Freedom from commutator trouble. This is especially valuable where fine chips are made, or where compressed air is used in connection with the machine. It is not such

a weighty point as it used to be, as the better makes of direct-current motors are now equally free from this kind of trouble.

c Most cities are now lighted by alternating current, so that city current can be used in smaller plants, provided the machine tools are arranged for this kind of motor.

66 *Direct-current motors.* The points in favor of the direct-current motor are:

a Wider air-gap, allowing a greater amount of wear in the bearings before the motor has to be repaired.

b The possibility of power and lighting-loads on the same circuits without the poor regulation due to inductive load.

c The possibility of using variable-speed motors. This is, perhaps, the greatest argument in favor of the direct-current motor. Though it is possible to run a great many machine tools by a motor, yet one of the greatest advantages of such a drive is not available, unless the motor is of the variable-speed variety.

67 *Alternating voltage.* When a decision has been reached as to the nature of the current to be employed, the next step will be to decide as to the voltage. A high voltage is likely to be in favor if distance was a controlling factor in the decision to use alternating current: for it is this possibility of using high voltage, which makes alternating current desirable under those conditions. Where the distances are relatively small, it becomes simply a matter of computation whether low copper cost plus the expenses for transformers, etc., will give greater or less economy than high copper cost without auxiliary apparatus. In a great number of cases, current is bought from some power company, and in such cases there is no choice. In any case, however, it remains to be decided to what voltage the current shall be transformed. Few engineers nowadays adopt the 440-volt current, on account of the greater danger, and for the same reason 500-volt direct current is very little used. It should be kept in mind that alternating current is more dangerous than direct current of the same voltage.

68 *Frequency and phase.* Frequency depends on the use to be made of the alternating current. In late years a compromise has been reached, which fills practically all wants of the shop by one single frequency, namely 60 cycles.

69 Though there is still some difference of opinion, the question of

the number of phases is now fairly well settled in favor of the three-phase current. It would be difficult, however, to point out the advantage of this system over the two-phase system, or vice versa, as far as use in shops is concerned.

70 *Direct voltage.* The choice of voltage is easier when direct current is used. There was a time when the multiple voltage seemed to take a strong hold on engineers for use in machine shops, and the writer must confess that he had strong faith in the ultimate success of this system. However, the development of the variable-speed motor has made the system somewhat superfluous and it has not been installed in any new shops of late. It might be said that, for all practical purposes, the system is dead.

71 There is, however, a kind of multiple-voltage system in use which deserves even at the present day the serious consideration of the engineer. This is the three-wire system, which allows of the use of 110 and 220 volts in the same shop. The 110–volt system alone would require a large amount of copper for power purposes, while the 220–volt installation leads to some difficulties in regard to lighting. However, there are many installations where the 220–volt system is used throughout, both for power and lighting, while the number of shops where a 110–volt system is used for both purposes is very small.

72 There are a few shops using 500 volts, but the number is very small as compared with the other voltages; and it is generally possible to trace the reason for such an installation to the fact that the 500-volt current is available because used for some other purposes, as, for instance, in the case of a repair shop for a street railway system. This system is not to be recommended for a shop (though it is economical in the use of copper), for the reason that it is dangerous and where there are a large number of circuits and much metal in buildings and machinery great care must be taken to avoid grounds.

73 *Combined alternating-current direct-current systems.* There is finally the combination of alternating and direct current to be considered. This combination has its advantages, especially where it is possible to purchase current from some large power company, which as a rule delivers its product as alternating current. Transformers reduce the voltage to the proper point at the entrance to the shop, and the low-voltage alternating current can be used for all purposes except for driving variable-speed motors, and perhaps some auxiliary apparatus such as magnetic clutches, lifting magnets, etc. As the cost of installation is generally low in such a case, and the price per unit of power usually less than it could be made for, such an arrangement is so

inviting that a number of objectionable features may be overlooked. The most serious objection, perhaps, to this method of driving a shop, is that the shop has absolutely no control over the supply of current, and there is nothing to be done in the case of a breakdown but sit down and wait. This is especially serious, as power delivered in this manner is generally transmitted over a long distance which increases the chance of a break in the wires especially in bad weather.

METHODS OF APPLYING MOTORS TO MACHINE TOOLS

74 The mode of application of a motor to a machine tool, the selection of the motor, and the lines along which economical results may be expected, are fairly well defined at the present time. The following tabulation shows the present state of the art.

75 *Bench lathes:* To be driven from a countershaft, attached to the wall or bench and driven in its turn by a motor. Any kind of motor, except a series-wound or heavily compounded motor will do. The object of the motor drive is to get the machine in the best possible location without regard to the location of the line shafting. A number of these machines may be driven by a common line shaft, driven by a motor.

76 *Speed lathes:* To be driven from a countershaft, located under the lathe, or by a direct-connected motor. In the latter case, a variable-speed motor is to be preferred, if direct current is available. Motor drive is recommended when the machine is used in the assembling department as the machine may then be placed where it is most needed, and the assembling department being generally of greater height than other departments crane service would interfere with countershafts. There will be no material gain, if the machine is to be used for ordinary shop operations.

77 *Engine lathes:* Various modes of motor-driving are in use. Some makers furnish motor-driven engine lathes as standard apparatus. Some have a headstock with a limited number of speeds and depend on a variable-speed motor to fill out the speeds of the lathe. Others apply a constant-speed motor, or one with a limited amount of variation, to an all-geared headstock. In general the use of this class of machines in the shop would naturally lead to group drive. Advantages of the individual motor drive lie in the possibility of completing a job in one setting. There is no material advantage, if the machines are used for regular manufacturing operations, except where the location demands the motor drive.

78. *Heavy engine lathes, forge lathes, etc.:* To be driven by a direct-connected motor. The motor should be direct-current, as these machines are too heavy to permit a convenient all-gear drive. If no direct current is available and there is only one machine of its class in the shop, and this is used for an occasional job only, an alternating-current motor could be used, leaving a wide gap in the speeds. If these machines are used for manufacturing purposes, however, it will pay to install a small synchronous connector. The speed range in the motor does not need to exceed two to one, though a wider range is better if obtainable without complications or large expenses. The position of the motor should be low, as the vibrations in the motor-support have a decided influence on the capacity of the machine, as well as on the repair bill. The output of this class of machine may easily be increased from 20 per cent to 25 per cent by motor drive.

79 Further advantages of the motor drive are, the possibility of placing the machine in the line of the routing of heavy work, and of placing it immediately under the traveling crane. This latter object may be reached with a belt-driven machine by placing the headstock under the gallery, if the construction of the shop lends itself to this arrangement, but the same convenience as that of the motor drive cannot be obtained.

80 *Axle lathes, wheel lathes and driving wheel lathes:* It is of the greatest importance that this class of machinery should have the highest possible efficiency, and the most convenient location. These machines are mostly used in railroad repair shops, where time saved does not mean merely the saving of some wages, but each day gained means an added day in the earning capacity of the engine. It is therefore important that these machines be motor-driven whenever installed in a railroad repair shop, though this does not mean that they should not be so driven if used for manufacturing. Direct current should be used. The economy of the motor drive should not be figured in increased output, but in reduction in time required to repair an engine.

81 *Chucking lathes:* Generally speaking, there is little reason why a chucking lathe should be motor-driven. Most chucking lathes are provided with the necessary mechanism to shift speeds quickly. A few types handling large work may be motor-driven to advantage, though practically the only advantage lies in the fact that small graduations in speed can be thus obtained. Such machines therefore require a variable-speed motor.

82 *Automatic screw machines:* Small machines of this class are

generally group-driven. Large machines may be motor-driven to good advantage. The larger sizes have generally one or two speeds for one piece of work, though these speeds may be varied when the machine is reset for a new piece of work. The speed given to the machine must naturally be proportional to the largest diameter to be turned, or in other words, to the size of stock used. This will reduce the speed for some of the operations, such as drilling, and reaming, far below the economical speed. The amount of time saved by the application of the variable-speed motor may be considerable. Where the construction of the machine permits, two motors, one for feed and one for speed, would give still better results. In all cases variable-speed motors should be used.

83 *Drill presses:* The only reason why a sensitive drill should be individually motor-driven is, that it is often used in an assembling department, where height of ceiling and crane service would make a belt drive awkward or impossible. Most sensitive drills have in themselves all the speeds required for their work, so that any type of motor will be adaptable. The motor may either be directly applied to the machine or may drive a countershaft on a stand, or be placed on the floor by the side of the machine in case the machine carries its own set of cones or other variable-speed device.

84 *Drill presses:* Generally speaking, the upright drill is used for manufacturing operations and does not require frequent changes of speed. There are, however, many exceptions, for instance, where upright drills are used to do all the operations on a piece by means of a jig. In this case frequent changes of tools, and therefore of speeds, are required, and an individual motor drive, whether direct-connected to the machine, or operating on the countershaft, is of the greatest benefit. No great benefit can be derived from a constant-speed motor with this type of machine. Radial drills may be considered the same as upright drills. There is an additional reason why radial drills should be motor-driven—they are often used in the neighborhood of the assembling floor.

85 *Boring machines:* Where boring machines are specialized, performing only one operation, there is no good reason why the motor drive should be preferred to belt drives. Where, however, the machine is used for a multiplicity of operations, such as drilling, boring, reaming and facing, a motor drive is beneficial if a variable speed motor is used. The range of speed of the motor should be as wide as possible, that no gears may have to be shifted for the entire set of operations on a single hole. Especially where a boring machine is used for facing, this variable speed will be found highly economical.

86 *Grinders:* Grinders in general require so many various movements driven from countershafts that it is hardly possible to apply a single motor directly to the machine. The best that can be done is to attach the countershaft to the machine and drive the former from a motor standing on the floor or on a bracket attached to the machine. In isolated cases it would be well to have one or more motors, each controlling a single operation, attached directly to the machine.

87 *Planers:* Planers in general are not benefited by the application of a motor, as the motor only complicates the difficulties of a planer drive. However, large planers which must be placed under a crane give better results when motor-driven on account of the facility of handling the work. Another possible advantage when using a variable-speed motor and controlling the speed of the motor at the end of the stroke, is that much higher return speeds can be obtained in connection with any desired cutting speed.

88 *Shapers, slotters etc.:* What is true of planers is also true of these classes of machines. Local conditions may make it advisable to drive them individually by motor, but generally speaking, there is no great benefit with this drive.

89 *Milling machines:* The larger sizes of knee-and-column type machines, if motor-driven, will give the best results if the motor is of the variable-speed type, especially where these machines are used for gang work. This is due to the fact that the speed of the mills is dependent on the largest cutter in the gang, while the feed is dependent on the smallest cutter, not counting the limitations due to the nature of the work. It is therefore important that the speed should be as close to the permissible limit as possible. When applied to this type of milling machine the motor should be as low down as possible, as vibrations in the machine have a marked effect on the quality of the finish.

90 *Planer-type milling machines:* In practically all cases this type of machine should be motor-driven in order that they may be located under a crane. It is not so very material, however, whether the motor is of the constant-speed or variable-speed type.

91 *Punches, bending rolls, shears, etc.:* This class of machinery, used largely for boiler, bridge, structural iron and ship-building work, is generally placed in high shops and under cranes, and in locations and directions most convenient for the routing of the work. The shops in which they are placed are generally large and contain a relatively small amount of machinery, so that the amount of transmission gearing required is large in proportion to the amount of

machinery. It is for this reason advisable in almost all cases to drive this class of machinery by an electric motor, which, of course, does not need to be of the variable-speed type.

92 It was not the intention to go into detail on the application of the motor to the machine tool, and the above should be considered as merely an enumeration of some of the important points on the most constantly used machines. It is in no way a treatise of motor drive applied to machine tools.

THE BUCYRUS LOCOMOTIVE PILE DRIVER

By Walter Ferris, South Milwaukee, Wis.
Member of the Society

The machine described in this paper is of some engineering interest as the most substantial and complete railway pile driver yet produced. Its special claims to consideration as a new development in mechanical engineering, however, lie in the unusual arrangement and strength of the self-propelling mechanism, and in the self-contained hydraulic turntable, whereby the entire machine, including trucks, is quickly lifted clear of the rails and turned end for end. The propelling engines, mounted on the car body and delivering more than 250 h.p., are connected to the axles of ordinary bogie trucks without interfering with the movements of the trucks in turning curves, passing over frogs, and the like.

2 The machine was designed to meet the requirement of the Atchison, Topeka & Santa Fe Railway system, for a pile driver capable of climbing any grade on their line and hauling its own cars of piles, tools, etc. The self-propelling pile drivers built hitherto are capable of moving themselves for short distances while at work, but from lack of sufficient steam capacity as well as engine power must have a locomotive in constant attendance. The services of this locomotive are usually charged against the bridge department of a railway at the rate of from $20 to $30 per day. After having used several of the ordinary self-propelling machines, A. F. Robinson, bridge engineer of the Santa Fe system, prepared specifications calling for a pile driver of much higher propelling power. This resulted in the designing by the Bucyrus Company of the machine herein described, which has been in active service on the Santa Fe lines since January 1909.

3 The general appearance of the machine is shown in the illustrations. Fig. 1 shows the machine with leaders folded in shipping position. Fig. 2 shows the leaders up ready for driving with the swinging frame turned across the track, and also shows how the coun-

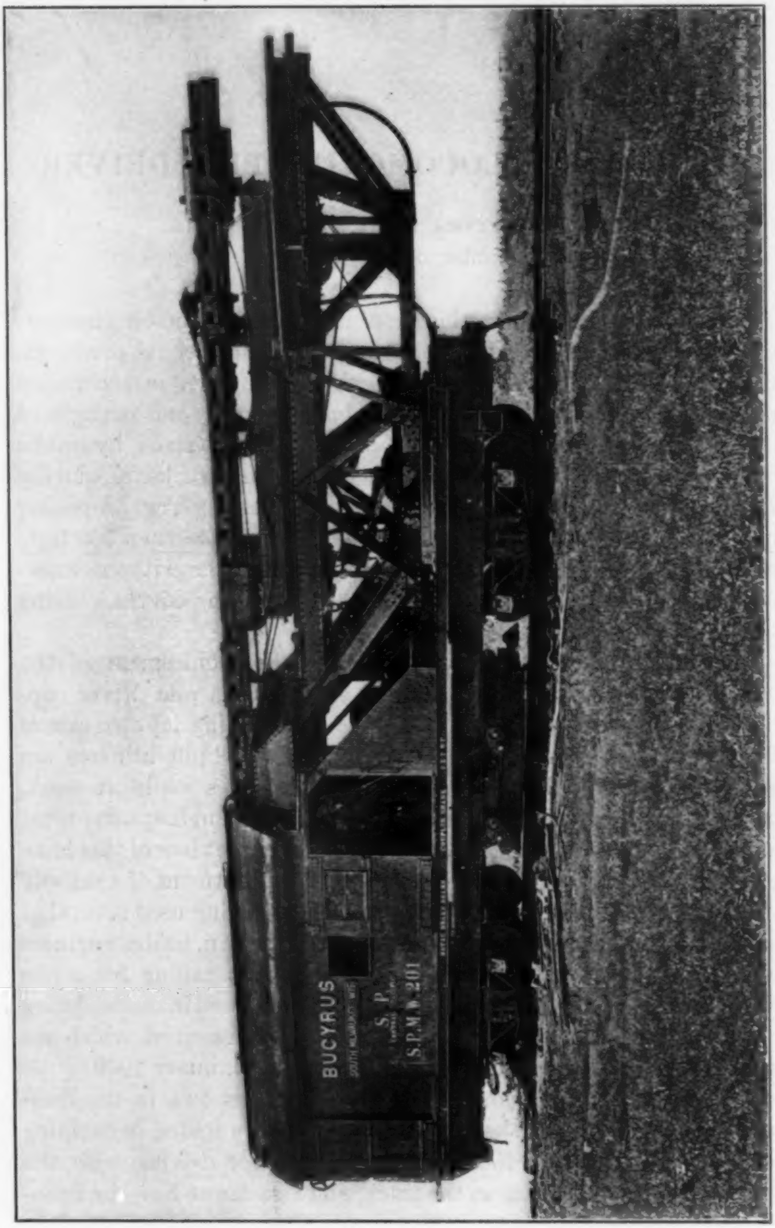


FIG. 1 THE BUCYRUS LOCOMOTIVE PILE DRIVER WITH LEADERS FOLDED IN SHIPPING POSITION

Fig. 2 The Leaders in Position for Driving with the Swinging Frame Across the Track

terweight on the opposite side of the swinging frame balances the weight of the leaders, keeping the machine always in a stable condition. In this position a pile can be driven 19 ft. from the center of the track.

4 Fig. 4 shows the machine standing on its hydraulic turntable with all wheels in the air. In this position and without any blocking the pile was picked up, put in place in the leaders and driven at a distance of 32 ft. from the center of the track. It was not desirable to drive this pile all the way in and the leaders were therefore backed down to clear the partially driven pile. The principal use of the hydraulic turntable, which will be described later on, is to turn the machine end for end when there is no railway turntable or "Y" available.

5 Fig. 3 shows the general arrangement of machinery. The car is 40 ft. long, built entirely of structural steel and steel castings. On the front end is mounted the swinging frame, shown in Figs. 1, 2 and 4, consisting of a pair of parallel trusses supporting the leaders at one end and a counterweight at the other end with the necessary parts for raising and lowering the leaders and swinging the entire frame to the right or left at right angles to the car body. This frame is swung by a large worm wheel, which also serves to raise and lower the leaders.

6 The latter operations are accomplished by means of the long worm-wheel hub projecting upward through the center pintle upon which the swinging frame revolves, a double-grooved sheave or drum being keyed to the upper end of the worm-wheel hub. This drum is provided with a clutch by which it can be engaged with the main base plate of the revolving frame. When this clutch engages with the swinging frame the latter moves with the worm wheel. When the clutch is out of engagement, however, and a brake is applied between the car body and the swinging frame, the revolution of the worm wheel does not carry the swinging frame with it, but merely turns the drum, which is keyed to the worm wheel.

7 The ropes leading from the drum to either end of the revolving frame are so arranged as to raise or lower the leaders. The details of the worm wheel, drum, clutch, etc., are clearly shown in Fig. 5. This figure also shows a large circular base plate on the car, for supporting the weight of the revolving frame. The latter is provided with four conical rollers which rest upon the finished upper surface of the base plate.

8 From Fig. 3 it may be seen that the leaders are mounted on a

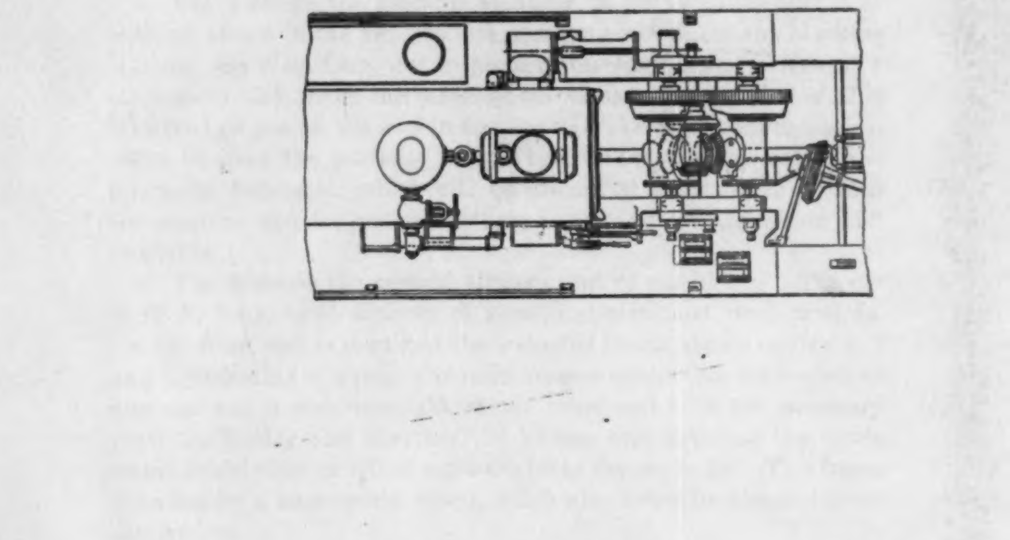
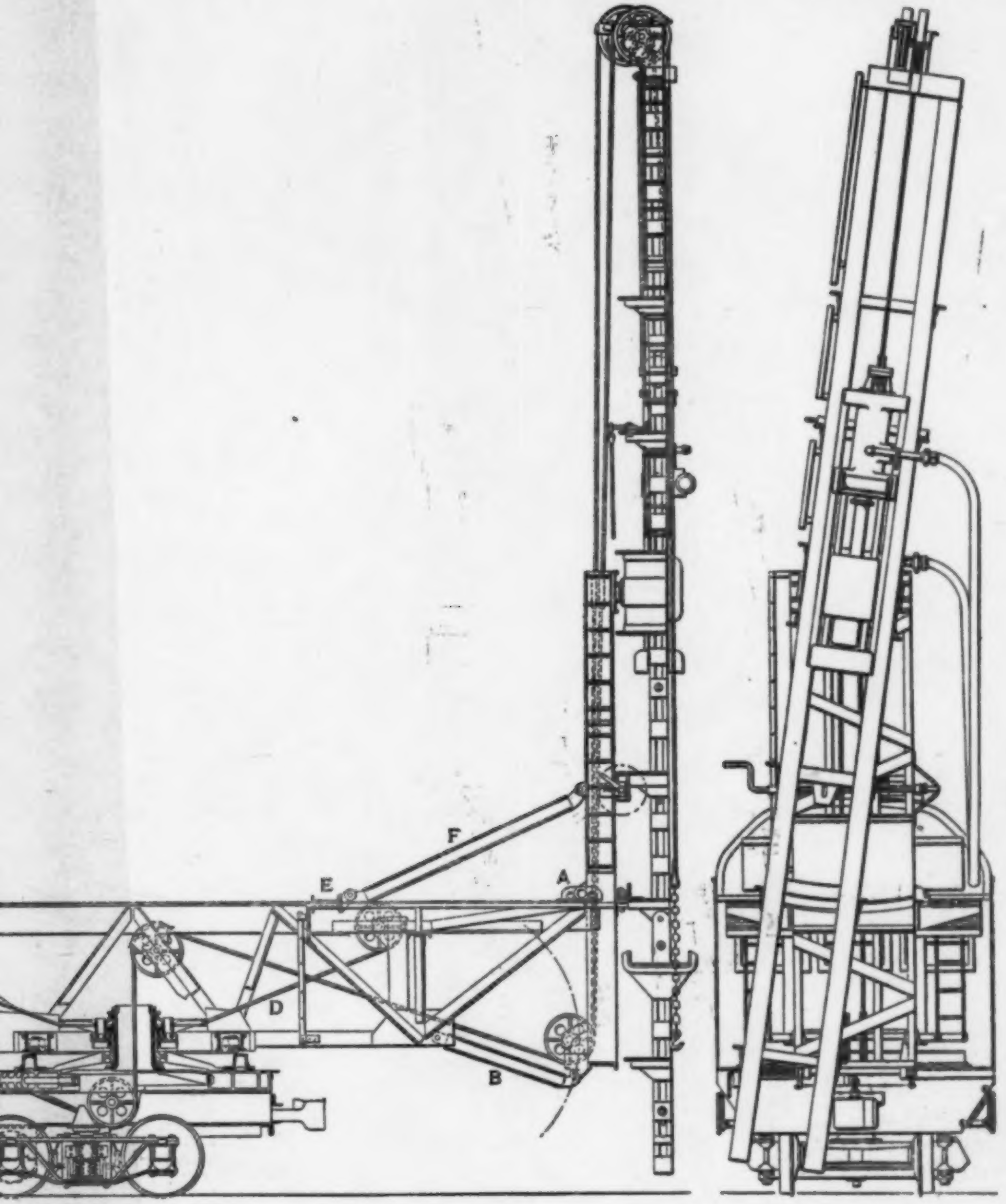


FIG. 3 SIDE AND FRONT ELEVATIONS AND PARTIAL P



Partial Plan of Bucyrus Locomotive Pile Driver

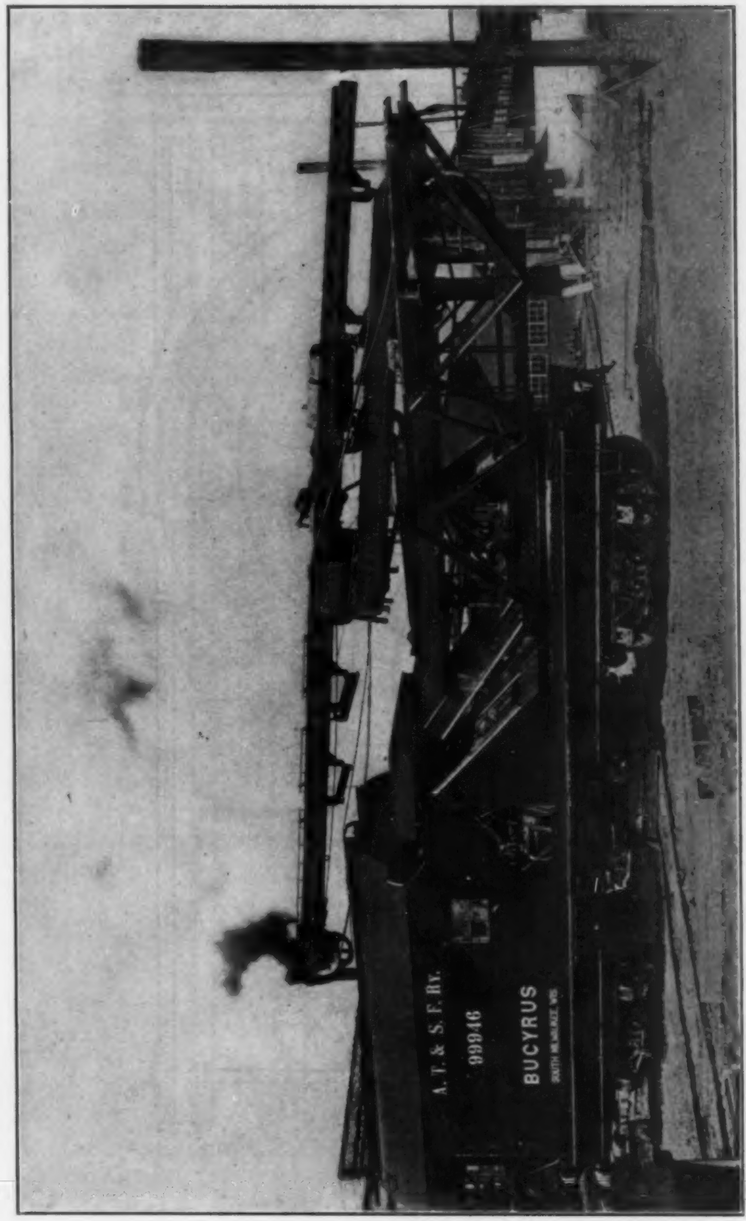
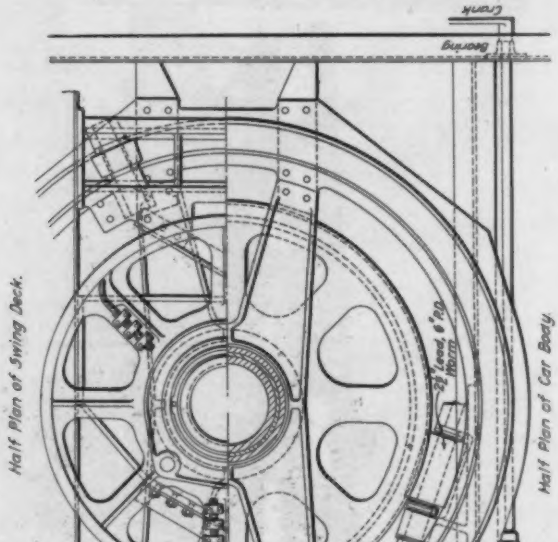


FIG. 4 THE PILE DRIVER STANDING ON THE HYDRAULIC TURNTABLE WITH BOTH TRUCKS OFF THE GROUND


Crank
Bearing
Half Plan of Swing Deck.
Half Plan of Car Body.
Swinging Deck
Worm
Coupling
Bearing

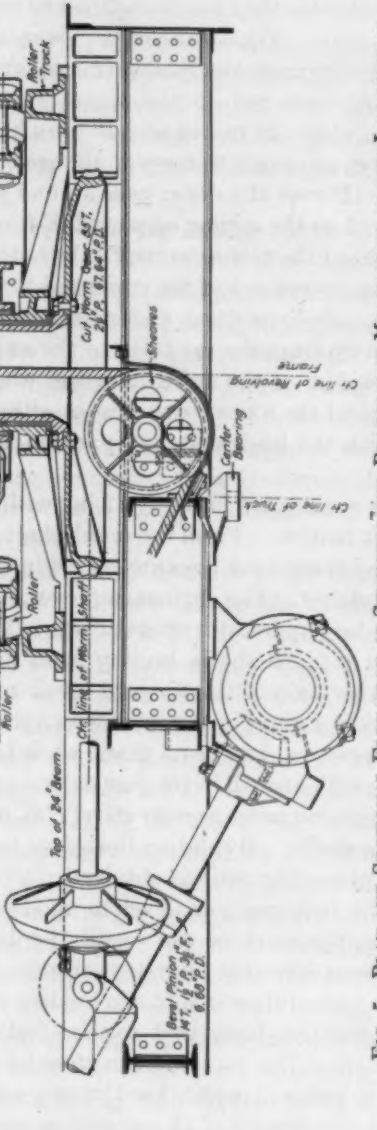


FIG. 5 PLAN AND SECTIONAL ELEVATION OF SWINGING AND PROPELLING MECHANISM OF THE LOCOMOTIVE PILE DRIVER

leader-raising frame by means of a pivot near the center of the leaders. A screw and nut device takes hold of the leaders some distance below the pivot and with this they can be inclined either to right or left so as to drive batter piles. The arrangement for raising and lowering the leaders acts directly upon the raising frame, which is carried by two rolling trucks *A* which roll on the top of the upper chords of the swinging frame, while the radius arm *B* takes hold of the lower end of the raising frame, causing it to move in the arc of a circle as indicated. The ropes *C* and *D* over the drum pass around suitable idler sheaves and are anchored to the sliding crosshead *E* forming a closed circuit. From this crosshead the raising arms *F* take hold of the raising frame, transmitting the movement of the crosshead to the latter. The hammer-hoist rope, pile-hoist rope and steam pipe (the last-named is not shown) run up from the car body to the swinging frame through the large hollow hub of the swinging worm wheel. The steam pipe is on the center and the ropes are so close on either side that they work equally well with the leaders in any position with regard to the car body.

9 The main engines are 11 in. by 12 in., with double cylinders and Stephenson link motion. From the crank shaft the two drums for the pile-hoist and hammer-hoist lines are geared in the usual manner with cone friction clutches. The engines, however, are much more powerful than would be required for these drums. The propelling gearing consists of two inclined shafts leading from the crank shaft of the engine to the rear axle of the forward truck and the forward axle of the rear truck. From Fig. 3 it will be seen that each of these shafts carries on its upper end two bevel gears, while the crank shaft carries a sliding sleeve with a small bevel gear on one end and a large one on the other end, the two meshing respectively with the two pairs on the inclined driving shafts. By sliding the sleeve to one end or the other a fast or slow propelling ratio is obtained.

10 With the fast gear, on level or moderate grades and with moderate loads, the machine can readily be driven at 25 miles per hour and has been driven at 30 miles per hour. With the slow gear the engines are powerful enough to slip the two driving axles and thus obtain all the tractive force that can be had with about 80,000 lb. weight on drivers. The machine can thus be used effectively as a switching engine and will readily haul its own weight with considerable additional load over grades of 1½ per cent or more. The acceptance-test of the first machine built was a run of 32 miles up a grade averaging 75 ft. to the mile, with a maximum of 97 ft. to the mile.

11 The lower ends of the inclined propelling shafts shown in Fig. 3 are provided with bevel pinions. These pinions mesh with bevel gears cast in one piece with large sleeves, as shown in Fig. 6. These sleeves surround the driving axles, a cored hole through the middle of the sleeves 10 in. in diameter providing about 2 in. clearance around the axles. The sleeves are supported by brackets rigidly attached to the car body with babbitted bearings. All this gearing is fastened to the car body only and remains in line without regard to the swivelling of the trucks.

12 The connection by which the driving torque is communicated from the propelling sleeves to the axles is also shown in Fig. 6. It consists of a modified type of universal joint so arranged that there is nothing to interfere with the axle passing through the middle. The propelling sleeve carries at one end a large flange with lugs supporting two pins *G*; these pins engaging with two bronze bushed lugs *H* formed on the inner side of the toggle casting *i*. On its outer side it carries another pair of lugs *J* on an axis at right angles to the axis of the pins *G* and these lugs *J* are connected to a U-shaped driving yoke *K*. The open end of this yoke is again pin-connected to a bracket *L* which is keyed to the axle.

13 Both pins, *G* and *M*, are made much longer than the lugs which engage them, to permit end play due to the displacements of the axle, as shown on the plan view in Fig. 6. As these two pin axes are at right angles to each other their combined slip will take care of any movement of translation, while the combined revolution of the parts around the pins *G*, *M* and *N* provides for any possible twisting. The wearing parts involved are six steel pins and six bronze bushings, all of the same size, and all parts are so made that the wearing surfaces can be replaced without taking the truck from under the machine. The pins are made hollow and are packed for continuous lubrication.

14 The method of detaching the driving gears when it is desirable to ship the pile driver in a freight train is slightly indicated in Fig. 3, at the rear axle of the front truck, where an operating lever is shown taking hold of the bearing which supports the bevel pinion at the lower end of the forward driving shaft. This bearing and the pinion are mounted in a sliding support, which enables the pinion to be drawn out of mesh with the bevel gear, permitting the propelling sleeves and gears shown in Fig. 6 to revolve freely with no gears in mesh. The same arrangement is provided on the rear truck.

15 In order to provide the necessary steam capacity for these propelling requirements, the boiler required is nearly three times the

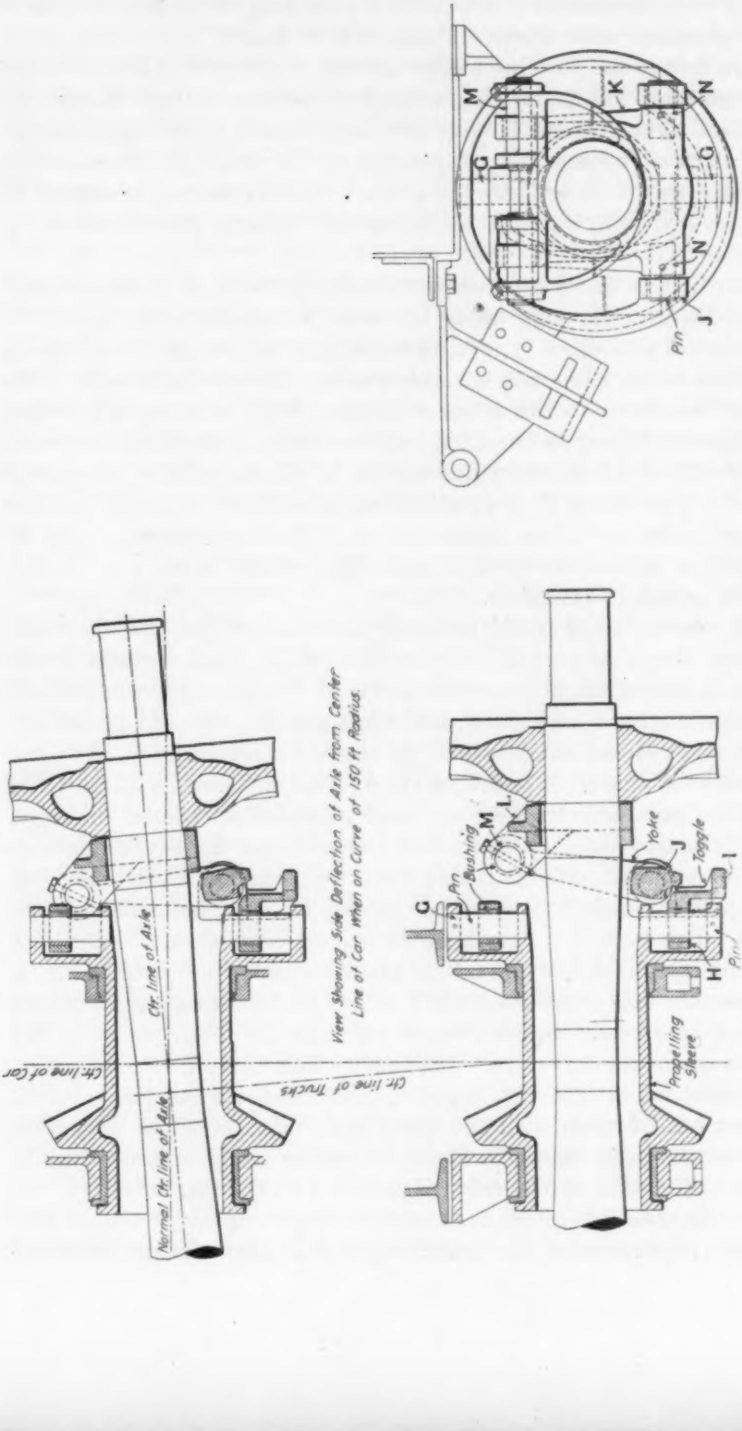


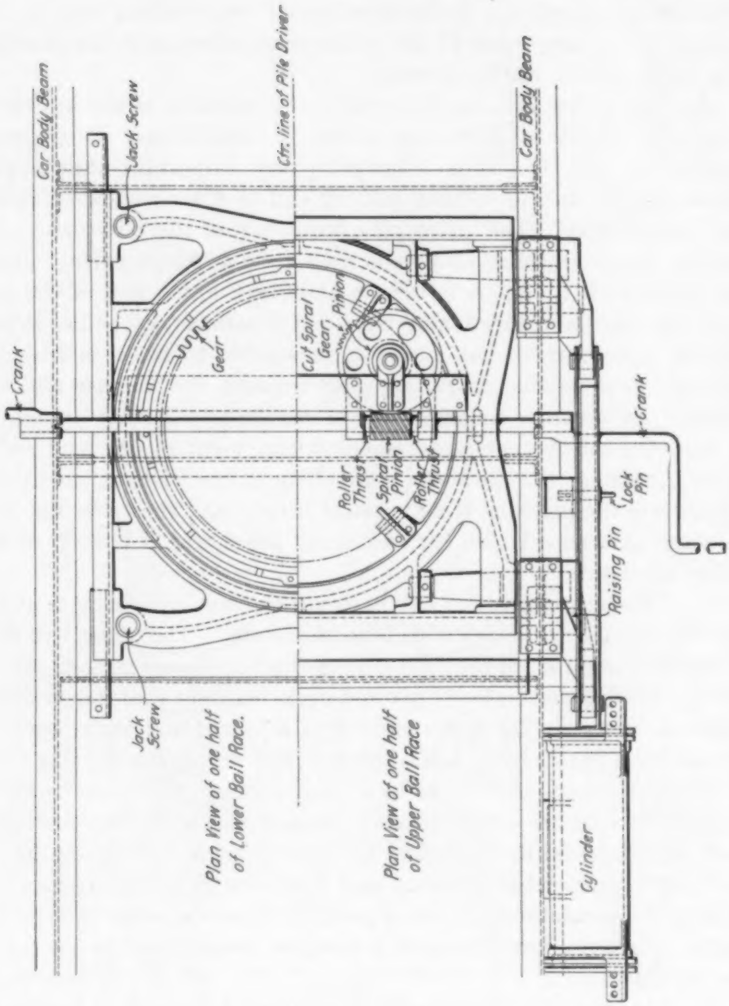
FIG. 6 SECTIONS AND END VIEW OF TOGGLE JOINT

size of those ordinarily furnished for pile drivers. The boiler is of the locomotive type, 54 in. in diameter, 15 ft. 9 in. long, having about 800 sq. ft. of heating surface and designed for 175 lb. pressure. This pressure is required only for steam economy on propelling runs, as the engines are so large that all the ordinary movements of the machine can be made with 100 lb. pressure.

16 One of the striking features of the machine is the hydraulic turntable, which is shown in action in Fig. 4, and in shipping position in Fig. 1. It is frequently very important that a pile driver should be able to turn end for end or else to work at either end indifferently. The latter plan requires that the boiler and pile-driving machinery shall all be mounted upon a swinging deck, which can be turned through a full circle and reach either end of the car. This plan has been thoroughly tried and is satisfactory as far as pile driving is concerned, but makes it impossible to get a sufficiently powerful and reliable propelling gear between the engines and the trucks. In the new machine, therefore, the pile-driving apparatus is mounted on the car body where it can work at one end only, thus obtaining the powerful propelling drive already described. To reverse the machine the hydraulic lifting jack shown in Fig. 7 is attached underneath the car and under the center of gravity of the entire structure.

17 This jack consists of two ball-race castings having races about 5 ft. in diameter provided with 2-in. steel balls. The upper ball race is carried upon a set of four bell cranks or levers *O*, two on each side of the car, the bell cranks being pivoted upon brackets *P* attached to the main car beams. The upper ends of each pair of bell cranks are connected by a parallel rod, while the rear bell cranks on the two sides of the car are connected across by a heavy shaft *Q*. This arrangement compels all four bell cranks to act in unison, and when they are operated by the hydraulic cylinders the four pins from which the upper ball race is suspended move up and down the same distance, maintaining the turntable at all times parallel to the car, even though the center of gravity may be quite a distance away from the center of the turntable.

18 The system of bell cranks is operated by a pair of hydraulic cylinders 12 in. in diameter, having about 28 in. stroke. One cylinder is located on each side of the car. The cylinders have trunk pistons with sufficient area between the outside of the trunk and the bore of the cylinder to provide lifting force enough to raise the turntable away from the track and put it in shipping position. While lifting


Car Body Beam
Jack Screw
Ctr. line of Pile Driver
Car Body Beam
Crank
Gear
Cut Spiral Gear
Pinion
Roller Thrust
Spiral Pinion
Roller Thrust
Crank
Lock Pin
Raising Pin
Jack Screw
Plan View of one half of Lower Ball Race.
Plan View of one half of Upper Ball Race
Cylinder

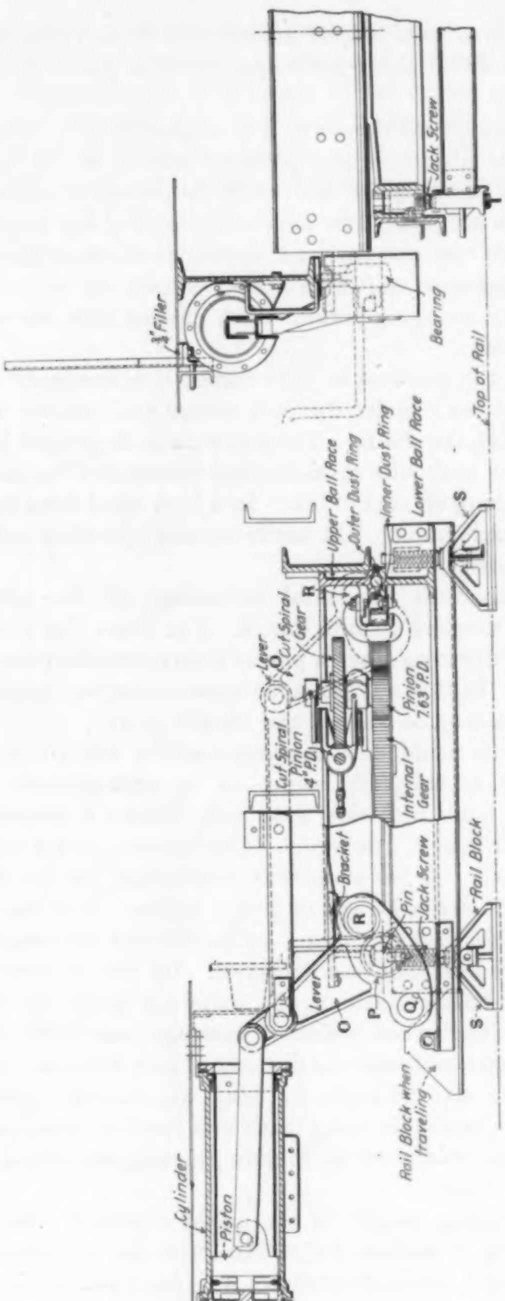


FIG. 7 PLAN AND SIDE AND FRONT ELEVATION OF HYDRAULIC TURNTABLE OF LOCOMOTIVE PILE DRIVER

the car the pressure acts upon the full area of the 12-in. piston. The working pressure of about 200 lb. per sq. in. is provided by the boiler feed pump.

19 The lower ball race, which is suspended from the upper ball race by suitable clips, is also provided with a set of chair castings which rest on the rails and can readily be placed under the four jack screws, which are located in the four corners of the lower ball race. The lower ball race also carries a circular rack, while the upper ball race has a transverse shaft with a crank on each end and a double gear reduction to a swinging pinion which meshes with the rack on the lower ball race.

20 When the machine is to be turned it is necessary only to put the chair castings *s* under the jack screws and run the latter down until they touch the chairs. The entire car is then raised by pumping water into the hydraulic cylinders and turned end for end by hand, two men working on each crank. In a high wind three men may be required on each crank. The entire turning operation occupies from 10 to 15 minutes.

21 An important incidental advantage of the turntable has already been touched upon in Par. 4. Fig. 2 and Fig. 4 show its use to enable the driver to reach a pile at a long distance from the center of the track. In this way, should occasion arise, any point within 32 ft. of the track may be reached and the pile driven.

22 The tests made since the first machine was put in operation indicate that it will fully come up to expectations. The first machine was built with slow gear only, having a maximum speed of 15 miles per hour. The results of its test on grades have already been mentioned. It has since been in constant use on the western divisions of the Santa Fe and on heavy grades. The fast propelling gear herein described has now been added and two machines thus equipped have been built and shipped. On one of these, built for the Canadian Pacific Railway, the following speed test was made. The machine hauled an ordinary passenger car from South Milwaukee to Racine and return, a distance of 12.6 miles each way. The run to Racine was made in 31 min., an average speed of 24.4 miles per hour, two miles being made at a speed of 30 miles per hour. The return run was made in 37 min., making an average speed of 20.5 miles per hour.

23 The shipping weight of the machine without the turntable, as shown in Fig. 3, is about 147,000 lb.; with the turntable, as shown in Figs. 1, 2 and 4, about 160,000 lb. It is equipped with either a No.

2 steam hammer or a 3500-lb. drop hammer, or both. The leaders are so made that either hammer can be used without change. The reach for driving piles is 18 ft. ahead of the center of the forward wheel, or 19 ft. on each side, as already mentioned; while with the turntable, 32 ft. on either side can be reached. The leaders are 40 ft. long. The construction is entirely of metal, except the house.

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ALEXANDER MILBURN CO., *Baltimore, Md.* The Milburn Light. 32 pp.

ALLIS-CHALMERS CO., *Milwaukee, Wis.* Folders and list of bulletins of pumping engine, flour mill, saw mill, electrical, steam engine and mining and crushing machinery depts. 1700 pp.

HANDY INDEX CO., *New York.* Handy Index f r architects, engineers, builders, and contractors, October 1909. 64 pp.

JOSEPH T. RYERSON & SON, *Chicago, Ill.* Stock list of iron, steel, boiler, and structural iron workers' supplies. October 1909. 144 pp.

UNDERFEED STOKER CO. OF AMERICA, *Chicago, Ill.* Publicity magazine, September 1909. 16 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society, and these are on file, with the names of other good men not members of the Society who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

079 Chief engineer in electrical department. Must have had experience in both direct-current and alternating-current design; must be capable of directing the work on both large and small apparatus, and have had actual manufacturing experience.

MEN AVAILABLE

317 Construction engineer, eleven years experience building construction of every kind; design, erection, installation of machinery and equipment, etc.; permanent position desired, to take entire charge of such work for manufacturing or engineering concern. Best references.

318 Junior, Lehigh graduate, four years experience in steel mills and one year on road as salesman. Desires commercial position, New York City preferred.

319 Superintendent desires position. Technical graduate. Extensive practical experience in manufacturing machine shop and iron foundry as executive and organizer. Qualified for position of trust and responsibility.

320 Member, graduate mechanical engineer with eighteen years experience, desires position in the East, with manufacturing corporation seeking to reduce cost of power operation or cost of output by the design of improved methods.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

BAILEY, H. Morrell (Junior, 1909), Engrg. Dept., Carnegie Steel Co., and *for mail*, Duquesne, Allegheny Co., Pa.

CAMPBELL, Jeremiah (Associate, 1896), 38 Kilby St., Boston, Mass.

CASE, Theo. Newton (1891; 1896), Klamath Falls, Ore.

CHURCH, Elihu C. (Junior, 1908), 4 E. 130th St., New York, N. Y.

COON, Thurlow E. (Junior, 1908), Mgr., Ball Eng. Co., 1809 Ford Bldg., Detroit, Mich.

DEAN, Arthur M. (Junior, 1907), Matheson Motor Car Co., Wilkes-Barre, Pa.

DE WOLFE, Edwd. Chas. (1899; 1906), Member of Russell-De Wolfe Co., 355 Dearborn St., and 586 Bryant Ave., Chicago, Ill.

ELDRED, Byron E. (1899; 1903), Pres. Commercial Research Co., 149 Broadway, New York, and *for mail*, Tuckahoe, N. Y.

ENNIS, J. B. (1909), Designing and Estimating Engr., Am. Loco. Co., 30 Church St., New York, N. Y., and *for mail*, 615 E. 24th St., Paterson, N. J.

FLANDERS, Ralph E. (Associate, 1908), Assoc. Editor, Machinery, New York, N. Y., and *for mail*, 18 Evergreen Pl., E. Orange, N. J.

FRY, Lawford H. (1905), Tech. Rep. in Europe of Baldwin Loco. Wks., 64, Rue de la Victoire, Paris, France.

GEORGE, J. Rowley (1899), Ch. Engr., Morgan Constr. Co., 21 Lincoln St., and *for mail*, 6 Bowdoin St., Worcester, Mass.

GIELE, Walter S. (Junior, 1908), 3 Hamilton Pl., New Brighton, S. I., N. Y.

GORE, Warren W. (1908), Charge Experimental Dept., Fairbanks-Morse Mfg. Co., and *for mail*, 950 Park Ave., Beloit, Wis.

HIGGINS, George F. (1886; 1906), 41 Mt. Vernon St., Melrose, Mass.

KIRCHHOFF, Charles (1882), 422 West End Ave., New York, N. Y.

NILES, Francis H. (Associate, 1907), 5437 Cornell Ave., Chicago, Ill.

PINNER, Seymour W. (Junior, 1909), Instr., Univ. of Mich., and *for mail*, 724 S. Ingalls St., Ann Arbor, Mich.

POPE, Harold L. (Junior, 1905), Engr., Matheson Motor Car Co., Wilkes-Barre, Pa.

RICHARDS, William A. (Junior, 1903), Univ. H. S., Univ. of Chicago, Chicago, Ill.

RIGGS, John D. (1892; 1907), 162 N. Pine Ave., Chicago, Ill.

ROSING, Wm. H. V. (1896), Mech. Engr., Mo. Pac. Ry. Co., and *for mail*, Hotel Berlin, St. Louis, Mo.

SETHMAN, George H. (Junior, 1899), Mech. and Elec. Engr., 125 E. 11th Ave., Denver, Colo.

SEWELL, J. G. Clifton (Junior, 1892), United Engrg. and Fdy. Co., Farmers Bank Bldg., Pittsburg, and *for mail*, 15 Hawthorne Ave., Crafton, Pa.

SHEPERDSON, John Wm. (Associate, 1908), Steam Engr., Cambria Steel Co., and *for mail*, 522 Second Ave., Johnstown, Pa.

SMITH, Edward S. (Junior, 1909), Box 172, University, Va.

SMITH, Jesse M. (1883), Manager, 1891–1894; V.P., 1894–1896, 1899–1901; Pres., 1908–1909; Life Member; Mech. and Elec. Engr. and Expt. in Pat. Causes, Rm. M-14, 220 Broadway, and *for mail*, 120 Riverside Drive, New York, N. Y.

SMITH, William E. (Junior, 1908), Babcock & Wilcox Co., and *for mail*, 316 E. Park Ave., Barberton, O.

THRELFALL, Wm. V. (1902), Rm. 601, Hitchcock Bldg., Springfield, Mass.

WAITE, Edward B. (Associate, 1902), Head of Instr. Dept., Am. Sch. of Correspondence, 58th St. and Drexel Ave., Chicago, Ill.

WHITING, S. B. (1880), Manager, 1880–1882; V.P., 1882–1883; 11 Ware St., Cambridge, Mass.

YOUNG, Gilbert A. (1906), Park Chambers, Magazine and Lake Sts., Cambridge, Mass.

DEATHS

GROVER, Lewis C.

NEW MEMBERS

FUNK, Nelson E. (1909), 23 City Hall Pl., New York, N. Y.

GAS POWER SECTION

CHANGES OF ADDRESS

GORE, Warren W. (1909), Charge Experimental Dept., Fairbanks, Morse Mfg. Co., and *for mail*, 950 Park Ave., Beloit, Wis.
HAYES, Frank A. (Affiliate, 1909), 9 Willow St., Boston, Mass.
SHORKEY, Edward Louis (Affiliate, 1909), 73 North St., Bethlehem, Pa.
SMITH, Bronson H. (Affiliate, 1908), Asst. Engr., Westinghouse, Church, Kerr & Co., New York, and *for mail*, 257 E. 23d St., Brooklyn, N. Y.
YOUNG, Gilbert A. (1908), Park Chambers, Magazine and Lake Sts., Cambridge, Mass.

NEW MEMBERS

HILLEBRAND, Herman (Affiliate, 1909), Ch. Engr., Portland Cement Co., and 702 East St., Gola, Kan.
HOPKINS, George Jay (Affiliate, 1909), Exper. Engr., 603 Harrison Ave., Beloit, Wis.
REARDON, Michael F. (Affiliate, 1909), Salesman, Genl. Elec. Co., 30 Church St., New York, N. Y.
SCHWEHR, George A. (Affiliate, 1909), Secy., Ohio Motor Co., Sandusky, O.

STUDENT SECTION

CHANGES OF ADDRESS

BOHNSTENGEL, Walter (Student, 1909), 1111 Kentucky St., Lawrence, Kan.
BOLGIANO, J. R. (Student, 1909), Towson, Md.
COBB, P. L. (Student, 1909), 419 Ross Ave., Wilkinsburg, Pa.
PARMELY, J. C. (Student, 1909), 1106 W. Univ. Ave., Urbana, Ill.
QUICK, R. L. (Student, 1909), 414 Darrow Ave., Plainfield, N. J.
RICHARDSON, L., Jr. (Student, 1909), 118 Linn St., Ithaca, N. Y.
VANDER VEER, J. H. (Student, 1909), 147 Pacific St, Brooklyn, N. Y.
WHEDBEE, Edgar (Student, 1909), Box 1176, Cascadilla Bldg., Ithaca, N. Y.

COMING MEETINGS

November and December

Secretaries or members of societies whose meetings are of interest to engineers are invited to send in their notices for publication in this department. Such notices should be in the editor's hands by the 18th of the month preceding the meeting.

ALABAMA LIGHT AND TRACTION ASSOCIATION
November 15, 16, annual convention, Birmingham. Secy., Lloyd Lyon, 158 Government St., Mobile.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
December 27, Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN CIVIC ASSOCIATION
November 15–19, Cincinnati, O. Secy., Richard B. Watrous, Harrisburg, Pa.

AMERICAN FEDERATION OF TEACHERS OF MATHEMATICS
December 28, 29, annual meeting, Baltimore, Md. Secy., C. R. Mann, University of Chicago.

AMERICAN INSTITUTE OF ARCHITECTS
December 14–16, annual convention, Washington, D. C. Secy., Glenn Brown, Octagon Bldg.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
December 8–10, annual meeting, Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
November 12, 33 W. 39th St., N. Y., 8 p.m. Paper: The Electric System of the Great Northern Railway Co. at Cascade Tunnel, C. T. Hutchinson, Mem.-Am.Soc.M.E.

AMERICAN MATHEMATICAL SOCIETY
November 27, University of Missouri, Columbia, Mo., Southwestern Section. Secy., O. D. Kellogg, 411 Hitt St.

AMERICAN PHYSICAL SOCIETY
November 27, University of Illinois, Urbana, Ill. Secy., Ernest Merritt, Ithaca, N. Y.

AMERICAN RAILWAY ASSOCIATION
November 17, annual meeting, Chicago, Ill. Secy., W. F. Allen, 24 Park Pl., New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
November 9, New York; Novemb r 13, St. Louis, Mo.; November 17, Boston, Mass.; December 7–10, annual meeting, 29 W. 39th St., New York. Secy., Calvin W. Rice.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS
November 9–11, annual meeting, Little Rock, Ark. Secy., A. Prescott Folwell, 239 W. 39th St., New York.

AMERICAN SOCIETY OF SWEDISH ENGINEERS
November 20, 271 Hicks St., Brooklyn, N. Y. Paper: Magnetic Separation of Iron Ores, N. V. Hansell. Secy., E. Hammerstrom.

APPALACHIAN ENGINEERING ASSOCIATION
November 5, 6, Washington, D. C. Papers by Dr. T. L. Watson, R. H. Edmonds, D. C. Weller, Prof. R. L. Morris, E. V. N. Heermance, Mr. Fernstrom. Secy., H. M. Payne, Morgantown, W. Va.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS
December 14, 15, annual meeting, New York. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

ASSOCIATION OF TRANSPORTATION AND CAR ACCOUNTING OFFICERS
December 14, 15, Chattanooga, Tenn. Secy., G. P. Conard, 24 Park Pl., New York.

CENTRAL ELECTRIC RAILWAY ASSOCIATION
November 18, Claypool Hotel, Indianapolis, Ind. Secy., A. L. Neereamer.

CENTRAL RAILWAY CLUB
November 12, Hotel Iroquois, Buffalo, N. Y., 8 p.m. Paper: Application of Electricity to the Movement of Freight, G. H. Condict. Secy., H. D. Vought.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
November 16, December 21, Prince George Hotel, Toronto. Papers: Gas Engines, their Origin and Commercial Use, D. M. Henderson; Gas Manufacture, C. G. Herring. Secy., C. J. Worth, Union Sta.

COLORADO SCIENTIFIC SOCIETY
December 18, annual meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

EMPIRE STATE GAS AND ELECTRIC ASSOCIATION
November 17, 18, 29 W. 39th St., New York. Secy., C. H. B. Chapin.

ENGINEERS CLUB OF ST. LOUIS
December 1, annual convention, 3817 Olive St. Secy., A. S. Langdorf.

FRANKLIN INSTITUTE
November 4, Section meeting, Philadelphia, Pa. Paper: The Open-Hearth Process, Prof. Bradley Stoughton.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS
November 16, annual meeting, Washington, D. C. Secy., M. S. Decker, Albany, N. Y.

NATIONAL COMMERCIAL GAS ASSOCIATION
December 12, 14, annual convention, Madison Square Garden, New York. Secy., L. S. Bigelow, Light Publishing Co., Willimantic, Conn.

NATIONAL GAS AND GASOLENE ENGINE ASSOCIATION
November 30, December 1, 2, LaSalle Hotel, Chicago, Ill. Secy., Albert Stritmatter, Cincinnati, O.

NATIONAL MUNICIPAL LEAGUE
November 15–19, Cincinnati, O. Secy., C. R. Woodruff, 121 S. Broad St., Philadelphia, Pa.

NATIONAL SOCIETY FOR PROMOTION OF INDUSTRIAL EDUCATION
December 1–3, annual convention, Milwaukee, Wis. Secy., J. C. Monaghan. 20 W. 44th St., New York.

NEW YORK RAILROAD CLUB
November 19, annual meeting, 29 W. 39th St., Secy., H. D. Vought, 95 Liberty St.

OHIO SOCIETY MECHANICAL ELECTRICAL AND STEAM ENGINEERS
November 19, 20, main annual meeting, Lima, O. Secy., David Gaehr, Schofield Bldg., Cleveland.

RICHMOND RAILROAD CLUB
November 8, annual meeting; December 13: Paper, Block Signals, Chas. Stephens. Secy., F. O. Robinson.

ROCHESTER ENGINEERING SOCIETY
December 10, annual meeting. Secy., John F. Skinner, 54 City Hall.

SHORT LINE RAILROAD ASSOCIATION
December 14, annual meeting, New York. Secy., J. N. Drake, 60 Wall St.

SOCIETY OF ENGINEERS OF EASTERN NEW YORK
November 10, Albany, N. Y. Paper on Gas Power, G. A. Orrok, Mem.Am.-Soc.M.E. Secy., W. R. Davis.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
November 18–19, annual meeting, 29 W. 39th St., New York, Secy., W. J. Baxter.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB
November 18, annual meeting, Candler Bldg., Atlanta, Ga. Papers on Oil Lamps, Front-End Arrangements, Draft-Rigging. Secy., A. J. Merrill, 218 Prudential Bldg.

WASHINGTON SOCIETY OF ENGINEERS
November 24, anniversary celebration. Secy., Paul Bausch.

WESTERN SOCIETY OF ENGINEERS
November 3, 20, December 1, 1735 Monadnock Blk., Chicago, Ill. Papers: Loss of Heat through Furnace Walls, W. T. Ray, Henry Kresinger; The Panama Railroad, Ralph Budd; Compressed Air in Contact Work, M. W. Briseler; River and Harbor Improvements at Chicago and the Calumet, T. H. Rees.

MEETINGS TO BE HELD IN THE ENGINEERING BUILDING

Date	Society	Secretary	Time
November			
3	Wireless Institute	S. L. Williams	7.30
4	Blue Room Engineering Society	W. D. Sprague	8.00
5	Explorers' Club	H. C. Walsh	8.30
6	Amer. Soc. Hungarian Engrs. and Archts.	Z. deNemeth	8.30
9	The American Society Mech. Engineers.	Calvin W. Rice	8.00
11	Illuminating Engineering Society	P. S. Millar	8.00
12	American Institute Electrical Engineers	R. W. Pope	8.00
16	New York Telephone Society	T. H. Lawrence	8.00
17–18	Empire State Gas and Electric Asso.	C. H. B. Chapin	All day
18–19	Naval Architects and Marine Engineers.	W. H. Baxter	All day

Date	Society	Secretary	Time
November			
19	New York Railroad Club	H. D. Vought	8.15
24	Municipal Engineers of City of New York	C. D. Pollock	8.15
December			
1	Wireless Institute	S. L. Williams	7.30
2	Blue Room Engineering Society	W. D. Sprague	8.00
4	Amer. Soc. Hungarian Engrs. and Archts.	Z. DeNemeth	8.30
7–10	The American Society Mech. Engineers	Calvin W. Rice	
9	Illuminating Engineering Society	P. S. Millar	8.00
10	American Institute of Electrical Engineers	R. W. Pope	8.00
17	New York Railroad Club	H. D. Vought	8.15
21	New York Telephone Society	T. H. Lawrence	8.00
22	Municipal Engineers of City of N. Y.	C. D. Pollock	8.15

OFFICERS AND COUNCIL

PRESIDENT

JESSE M. SMITH .... New York

VICE-PRESIDENTS

L. P. BRECKENRIDGE .... Urbana, Ill.
FRED J. MILLER .... Center Bridge, Pa.
ARTHUR WEST .... E. Pittsburg, Pa.

Terms expire at Annual Meeting of 1909

GEO. M. BOND .... Hartford, Conn.
R. C. CARPENTER .... Ithaca, N. Y.
F. M. WHYTE .... New York

Terms expire at Annual Meeting of 1910

PAST PRESIDENTS

Members of the Council for 1909

AMBROSE SWASEY .... Cleveland, O.
JOHN R. FREEMAN .... Providence, R. I.
FREDERICK W. TAYLOR .... Philadelphia, Pa.
F. R. HUTTON .... New York
M. L. HOLMAN .... St. Louis, Mo.

MANAGERS

G. M. BASFORD .... New York
A. J. CALDWELL (Deceased) .... Newburg, N. Y.
A. L. RIKER .... Bridgeport, Conn.

Terms expire at Annual Meeting of 1909

WM. L. ABBOTT .... Chicago, Ill.
ALEX. C. HUMPHREYS .... New York
HENRY G. STOTT .... New Rochelle, N. Y.

Terms expire at Annual Meeting of 1910

H. L. GANTT .... New York
I. E. MOULTROP .... Boston, Mass.
W. J. SANDO .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

TREASURER

WILLIAM H. WILEY .... New York

HONORARY SECRETARY

F. R. HUTTON .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

ARTHUR M. WAITT .... New York

SECRETARY

CALVIN W. RICE .... 29 West 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Jesse M. Smith, *Chairman*
F. R. Hutton
Alex. C. Humphreys
Fred J. Miller
F. M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (1), *Chairman*
Geo. J. Roberts (3)
Edward F. Schnuck (2)
Robert M. Dixon (4)
Waldo H. Marshall (5)

HOUSE

Henry S. Loud (1), *Chairman*
Bernard V. Swenson (3)
William Carter Dickerman (2)
Francis Blossom (4)
Edward Van Winkle (5)

LIBRARY

John W. Lieb, Jr. (4), *Chairman*
Ambrose Swasey (2)
H. H. Suplee (1)
Leonard Waldo (3)
Chas. L. Clarke (5)

MEETINGS

Willis E. Hall (1), *Chairman*
L. R. Pomeroy (3)
Wm. H. Bryan (2)
Charles E. Lucke (4)
H. de B. Parsons (5)

MEMBERSHIP

Henry D. Hibbard (1), *Chairman*
Francis H. Stillman (3)
Charles R. Richards (2)
George J. Foran (4)
Hosea Webster (5)

PUBLICATION

Arthur L. Williston (1), *Chairman*
H. F. J. Porter (3)
D. S. Jacobus (2)
H. W. Spangler (4)
Geo. I. Rockwood (5)

RESEARCH

W. F. M. Goss (5), *Chairman*
R. C. Carpenter (2)
Jas. Christie (1)
R. H. Rice (3)
Chas. B. Dudley (4)

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

SPECIAL COMMITTEES
1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
G. T. Voorhees
A. P. Trautwein
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
F. R. Hutton
G. M. Basford
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
L. D. Burlingame
Charles Whiting Baker
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
Geo. M. Bond
William J. Baldwin
Stanley G. Flagg, Jr.

On Thurston Memorial

Alex. C. Humphreys, *Chairman*
Chas. Wallace Hunt
R. C. Carpenter
J. W. Lieb, Jr.
Fred J. Miller

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
E. R. Fellows
Hugo Bilgram
C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman*
L. P. Breckenridge
Edward F. Miller
Edward T. Adams
William Kent
Arthur West
George H. Barrus
Charles E. Lucke
Albert C. Wood

On Land and Building Fund

Fred J. Miller, *Chairman*
James M. Dodge
R. C. McKinney

SOCIETY REPRESENTATIVES

1909

On John Fritz Medal

HENRY R. TOWNE (1) — F. R. HUTTON (3)
AMBROSE SWASEY (2) — CHAS. WALLACE HUNT (4)

On Board of Trustees United Engineering Societies Building

CHAS. WALLACE HUNT (1) — F. R. HUTTON (2)
FRED J. MILLER (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE OF THE AM. SOC. M. E.

On National Fire Protection Association

JOHN R. FREEMAN — IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS — F. W. TAYLOR

On Government Advisory Board on Fuels and Structural Materials

GEO. H. BARRUS — P. W. GATES
W. F. M. GOSS

On Advisory Board National Conservation Commission

GEO. F. SWAIN — JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS — FRED J. MILLER

NOTE.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION
1909

CHAIRMAN
F. R. Low

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman, *Chairman*
G. I. Rockwood
F. R. Hutton
H. H. Suplee
R. H. Fernald

GAS POWER MEMBERSHIP COMMITTEE

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Albert A. Cary
A. F. Stillman
H. V. O. Coes
G. M. S. Tait
A. E. Johnson
George W. Whyte
F. S. King
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Cecil P. Poole, *Chairman*
E. S. McClelland
R. T. Kent
C. T. Wilkinson
C. W. Obert

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
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H. R. Cobleigh
T. M. Phetteplace
G. D. Conlee
G. J. Rathbun
R. S. de Mitkiewicz
W. Rautenstrauch
L. V. Goebbels
S. A. Reeve
L. N. Ludy
A. J. Wood
A. L. Rice

GAS POWER INSTALLATIONS COMMITTEE

J. R. Bibbins, *Chairman*
A. Bement
L. B. Lent

GAS POWER PLANT OPERATIONS COMMITTEE

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J. D. Andrew	N. T. Harrington	J. P. Sparrow
W. H. Blauvelt	J. B. Klumpp	A. B. Steen
V. Z. Caracristi	G. L. Knight	F. W. Walker
E. P. Coleman	J. L. Lyon	C. W. Whiting
C. J. Davidson	D. T. MacLeod	Paul Winsor
W. T. Donnelly	V. E. McMullen	T. H. Yawger

GAS POWER STANDARDIZATION COMMITTEE

C. E. Lucke, *Chairman*
E. T. Adams
Arthur West
James D. Andrew
J. R. Bibbins
H. F. Smith
Louis C. Doelling

OFFICERS OF STUDENT BRANCHES

STUDENT BRANCH	AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter		C. F. Hirshfeld
	1909			
Armour Inst. of Tech. Chicago, Ill.	March 9	C. F. Gebhardt	N. J. Boughton	M. C. Shedd
Leland Stanford, Jr., University, Palo Alto, Cal.	March 9	W. F. Durand	P. H. Van Etten	H. L. Hess
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. M. Russell	P. Gianella
State Agri. College of Oregon, Corvallis, Ore.	March 9	Thos. M. Gardner	J. J. Karstetter	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. A. Kirk	J. R. Jackson
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	H. S. Coleman	John Garver
New York Univ., New York.		C. E. Houghton		Andrew Hamilton
Univ. of Illinois, Urbana, Ill.		W. F. M. Goss	W. F. Colman	S. G. Wood
Penna. State College State College, Pa.				